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by

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This thesis presents a high resolution stochastically based simulation to be used in the evaluation of measures of effectiveness to determine the optimal basis of issue of mine/countermine equipment. A discussion of the types of breaching equipment and the tactics involved is used to provide background for the simulation.

Several measures of effectiveness are used to determine how the various configurations of breaching equipment affect the battle and battle outcome.

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Mine/Countermine Basis of Issue Optimization Plan

by

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requirements for the degree of

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ABSTRACT

The mobility and effective employment of tanks in a future conflict may be seriously threatened by enemy land mines.

This thesis presents a high resolution stochastically based simulation to be used in the evaluation of measures of effectiveness to determine the optimal basis of issue of mine/countermine equipment. A discussion of the types of breaching equipment and the tactics involved is used to provide background for the simulation.

Several measures of effectiveness are used to determine how the various configurations of breaching equipment affect the battle and battle outcome.

THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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I. INTRODUCTION

A. BACKGROUND

The United States Army currently possesses the most advanced tank in the world, the M1 Main Battle Tank. It is able to move faster, shoot more accurately, and maneuver better than any comparable system. Yet the emphasis on mobility and the high degree of technical sophistication which we have placed on the M1 may be negated by even a World War II vintage anti-tank mine. The use and effectiveness of landmines against tanks have substantially increased since World War I, while our ability to counter the landmine threat has not changed dramatically in the last 40 years. Proponency disagreements appear to have hindered the thorough formulation and development of a comprehensive mine clearing system while the search for and development of one device that would effectively perform all countermine functions has been understandably futile.

While there have been substantial advances in the development of new types of mines and minelaying equipment, the methods of detecting and clearing mines still leave much to be desired [Ref. 1]. There are still very few mine detectors which will detect nonmetallic mines, the most likely type to be found on the battlefield today. Once the mines have been detected they must be cleared or bypassed. The United States has been developing several systems to

enable units to breach complex obstacles. Two of these are the track width mine plow (TWMP) and the track width mine roller (TWMR). Both the plow and the roller have inherent strengths and weaknesses, and neither of them is totally effective.

B. PURPOSE AND GOALS

Although detailed combat models (such as JANUS or CASTFOREM) are heavily used at the tactical level, some analysts and users have doubts about the use of this kind of model when evaluating the impact of a new piece of equipment entering the inventory. Detailed combat models are costly to build, costly to run, are quite demanding in data base requirements, not easily modified, essentially impossible to use for sensitivity analysis and other parametric studies, and not easily communicated to decision makers.

On the other hand, a model can be built rather quickly and inexpensively in order to answer questions of a particular nature. The model is written with specific goals in mind and specific output desired. Development of that type of model is the subject of this thesis. It examines various mixes of the TWMP and the TWMR with the goal of determining the optimal type and number of systems that can effectively be used to breach a series of minefields by an armor battalion. The countermine mix must provide effective mine neutralization in the breached lanes

for the assault with minimum loss of momentum and time, and minimize breaching and assault force losses due to mine detonations.

By constructing the model in this fashion, the number of variables that could impact on the output is kept to a minimum and the output and analysis will provide results with an acceptable degree of accuracy.

C. METHODOLOGY

Through the use of a high resolution combat simulation using clearing and survivability data, output is generated which is analyzed and then evaluated under various measures of effectiveness which have been developed to provide comparisons between different force and equipment configurations. Figure 1 demonstrates the process by which the evaluation will take place. Entering the configuration or inventory, the minefield parameters and enemy actions, and the assault force's actions and decisions into the simulation model results in an exiting vehicle inventory, transit times and unit status codes which are then used to evaluate the desired measures of effectiveness.

In Chapter 2, the Concepts of Mobility and Operations are discussed. Additionally, a discussion of the options available to a unit commander in countering are examined in detail. The characteristics of the breaching equipment,

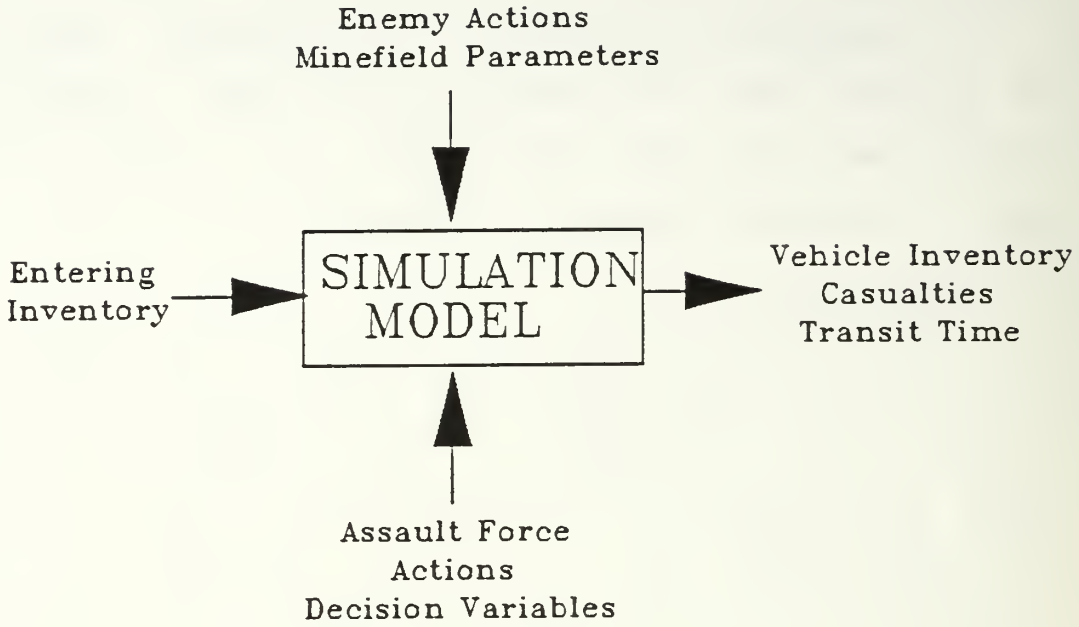


Figure 1. Functional Simulation and Analysis Model

their normal employment and the development of the measures of effectiveness used to analyze the output from the simulation are examined.

In Chapter 3, the layout and flow of the simulation are discussed, along with detailed descriptions of the various modules that compose the model. The tactical scenario which was used in the model development and simulation is included.

Chapter 4 deals with the output analysis and evaluation of the measures of effectiveness used to determine the optimal force structure.

Finally, Chapter 5 provides recommendations for possible future enhancements to the model as well as possible utilizations of this model and other models of this type. In the appendices, variables used in the simulation are defined, the computer code is listed and described in detail, and the data files used in the simulation are presented.

II. NATURE OF THE COUNTERMINE PROBLEM

A. CONCEPT OF OPERATIONS AND MOBILITY

Mobility is oriented toward reducing or negating the effects of existing or reinforcing obstacles to improve movement of maneuver/fire units and movement of critical supplies [Ref. 2].

The concentration of forces and weapons at the critical time and place is a prerequisite for winning both offensive and defensive battles. The firepower and cross-country mobility offered by tanks make them the most important conventional battlefield weapon of today and the future. The overall mobility of the forces may be countered through the use of existing and reinforcing obstacles. Existing obstacles may be considered to be those natural or man made obstacles which currently exist on the battlefield. Reinforcing obstacles are specifically designed to impede the movement of enemy units and are constructed when possible to complement existing obstacles, friendly fires, and scheme of maneuver.

Obstacles are intended to be employed in depth along the expected enemy axis of advance with the intent of stopping, delaying, or redirecting enemy tanks to a location advantageous to the employment of anti-tank weapons. If the obstacles are properly employed they are likely to delay an enemy unit attempting to pass through

them. A delay that occurs within the range of anti-tank weapons covering the obstacles is likely to significantly increase the effectiveness of those antitank weapons. The primary purpose of obstacles is to enhance the effectiveness of friendly fires, to delay or disrupt enemy formations, to allow the tactical commander to use economy of force, and to enable him to protect his flanks.

The Soviet Army places great emphasis on landmine warfare, and they possess rapid and effective means of both laying and breaching minefields. They are likely to use mines extensively in defensive and offensive operations. By doctrine, their minefields are located at the front of defensive positions and are covered by antitank and general supporting fires. Soviet minefields are employed to disrupt the enemy attack by causing vehicle casualties, reducing overall momentum of the attack, and forcing the enemy into confined areas. Minefields located within the main area of defense are employed to provide kill zones for anti-tank weapons and restrict enemy movement to designated areas where the concentrated fires of all weapons are focused on the attacking forces. They are not used with the idea of blocking or destroying the enemy force, but to reinforce natural obstacles, scare the enemy, divert his attention from the defender and influence his maneuver. [Ref. 3]

Mines are widely recognized as the most effective reinforcing obstacle. While other obstacles can only act passively on tanks, mines have proven themselves to be capable of destroying tanks by themselves. The achievement during the combined employment of anti-tank weapons and anti-tank mines of a greater number of casualties than would be possible by summing the casualty producing capabilities of each acting independently is commonly acknowledged and is referred to as a synergistic effect.

To counter this threat of decreased mobility, tank mounted countermine sets of plows and rollers will give a tank company limited capability to conduct hasty minefield breaches. The countermine mix must provide accurate identification of minefield encounters, provide effective mine neutralization in the breached lanes, provide lanes for the assault force with minimum loss of momentum and time, and minimize breaching and assault forces losses due to mine detonations [Ref. 4].

The roller/plow team has distinct limitations. The roller, by virtue of the fact that it always travels in contact with the ground, is constantly detecting and clearing a path immediately in front of the vehicle on which it is mounted [Ref. 4]. However, due to the weight of the device, the breaching vehicle's mobility is greatly reduced. Additionally, due to the roller's method of neutralizing mines by detonation, it cannot withstand the

rigors of constant breaching operations. The mine plows are not designed to detect mines but to clear a path directly in front of the plow tank once a minefield is encountered/ detected. Since the plow tank travels with the plow in the raised mode, the crew of the plow tank must be able to visually detect the minefield in order to determine when to employ the plow [Ref. 4].

B. TACTICAL RESPONSES TO MINEFIELDS

The offensive force commander must keep one principle in mind when a minefield is encountered: maintain the momentum of the offense. Obstacles must not stop or impede the movement for unusually long periods of time. The tactical commander has three alternatives when faced by an obstacle; he may breach, bypass, or "force through" the obstacle [Ref. 5].

1. The Bypass

To conserve time and manpower, obstacles are bypassed whenever possible. However, if the enemy has employed the obstacles properly, they will be difficult to bypass. [Ref. 6]

2. The Breach

A breach is conducted when the unit possesses the proper equipment to breach. Two methods of breaching may be employed: the assault breach or the deliberate breach. [Ref. 6] We are concerned only with the assault breach. The assault/hasty breach is done quickly during either a

hasty or deliberate attack. The main objective is speed in gaining the breach, since delays may be costly in terms of casualties due to direct fires covering the obstacle. With the mineplow and mineroller, it maybe quicker and easier to attempt a breach than to bypass.

3. The Force Through

The "force through" or "bull" tactic is attempted when no other way to overcome the obstacle exists. The unit does not possess any breaching equipment and will drive through the minefield in hopes of clearing a path. Heavy losses are expected when this tactic is employed. [Ref. 7]

C. TYPES OF BREACHING EQUIPMENT

The track width mine roller (TRMR) is a 10 ton assembly consisting of two banks of rollers. The rollers detect mines by detonating them as it rolls over them. There is a dog bone and chain assembly between the two banks of rollers to activate any tilt rod mines which could cause a belly kill on the breaching vehicle. [Ref. 6] Mine rollers have the potential to provide countermine detection and neutralization only as long as the single impulse pressure fuze mine remains the predominant fuze type. [Ref. 8]

The track width mine plow (TRMP) weighs 3.5 tons and consists of two plow blades. The plow removes surface laid or buried mines from the path of the vehicle's tracks, the tines penetrate the ground to dislodge buried mines and

bring them to the surface where they are cast aside. A dog bone and chain assembly is used to clear tilt rod mines in the same manner as the TWMR. [Ref. 9] It possesses the potential to provide effective mine clearing of surface laid mines and under certain terrain conditions, mines laid below the surface [Ref. 8].

Sweeping operations to clear a path through a minefield is carried out by the roller and plow sections simultaneously or by the roller section alone. When moving through a mined area, travel should be in as straight a line as possible and no sharp turns should be executed, otherwise a mine unearthed by the plow may pass under the tank's tracks. When choosing a movement route, it is desirable that this path lie along the smoothest possible course through the minefield. [Ref. 10] The best overall results are normally achieved when the two systems are used in tandem, with the roller leading until it detects (detonates) a mine. The plow then digs in and leads through the minefield, followed by the roller which proofs the lane. Once the minefield is passed, if further mines are anticipated, the roller resumes the lead. [Ref. 11] The company/team sized element conducting the hasty breach through a threat minefield and continuing on to seize the objective can effectively exert command and control of only one breach. [Ref. 4]

D. MEASURES OF EFFECTIVENESS

The measures of effectiveness concentrate on the principal purposes of countermine equipment which are to decrease the amount of time the unit is exposed in the attack, reduce delay time due to minefields, and to change the force ratio for the attackers. The MOEs are quantitative indicators of the equipment's ability to affect the battle outcome compared to various base case situations, (i.e. when the battlefield is void of obstacles and the battle outcome when the battlefield has minefields and the attacking unit does not possess any breaching/clearing equipment).

An integral factor in the determination of the number of breaching systems is the vulnerability of a specific device to direct or indirect fires, since the loss of a device (due to damage or failure) before or during the breach would require the employment of additional devices. Because of their relatively high degree of accuracy and standard coordinated employment with a minefield, direct fires are generally considered to be the predominant threat.

The final factor that must be considered in the MOE development is the expected reliability and survivability of the clearing or neutralizing device. This reliability denotes the probability of the device actually clearing or neutralizing a mine it encounters and the survivability of

the device is the ability to withstand the rigors of mine detonations which may be encountered when clearing the obstacle.

The primary question of how the number of pieces of breaching equipment affects the battle is best answered by measuring the number of casualties suffered by the attacking force. If the equipment accomplishes its mission, such as allowing a rapid breaching of obstacles, there should be a decrease in the number of casualties due to both mine detonations and direct fire kills, or the minimum range between opposing forces should have decreased.

The MOEs are as follows:

1. percent of blue casualties due to direct fire.
2. percent of blue casualties due to mine detonations
3. percent of blue casualties due to both mine detonations and direct fire.
4. number of blue casualties due to mines/number of pieces of breaching equipment available.
5. number of blue casualties due to direct fire/number of pieces of breaching equipment available.
6. number of total blue casualties/number of pieces of breaching equipment available.
7. Number units going to defensive posture over 50 repetitions of the model.
8. Time of units going to defensive posture (number in the initial, early, middle and late portions of the battle).
9. Average length of battle.
10. Minimum range of blue forces

11. Rate of battle losses = number of casualties/minute of battle.

III. MODEL DEVELOPMENT

The model developed for this thesis is a time sequenced, stochastic, battalion level, force-on-force simulation. The model conducts the battle in uniform time steps of 30 seconds each. Figure 2 provides the general scheme for the sequence and flow of events in the model. The pertinent elements for the landmine simulation and analysis problem are the mine countermeasures equipment and the maneuver units. Other necessary values are the mine countermeasures equipment at the assault site and the characteristics of the equipment.

The simulation has been written to allow for maximum user flexibility while maintaining a simple and transparent structure. Unit formations can be easily changed, numbers and types of equipment are easily modified, and even the maneuver network can be easily changed. The full flexibility of the model is discussed in detail as each module is explored. Although the program code is listed in its entirety in Appendix B, the critical portions are discussed in the following sections.

The sequence of events for each time interval (30 seconds) contains six main phases: unit status, unit location, movement, Red detect/fire, Blue detect/fire and battle termination/results. The movement phase applies to the blue forces only. Generally, every blue unit is advanced the total distance it is able to travel based on

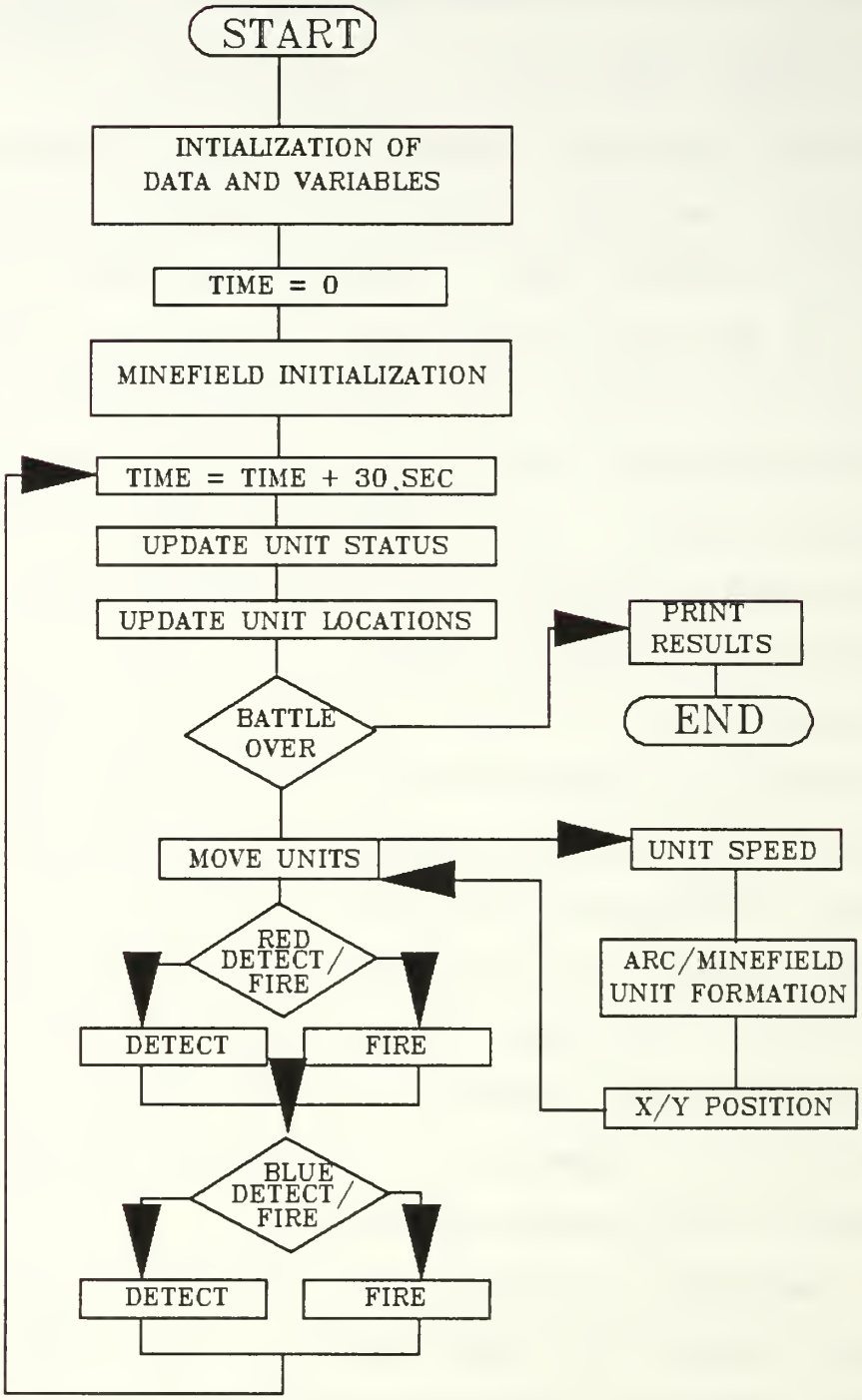


Figure 2. Model Flowchart

unit formation, types of equipment, terrain and location. The detection for both the red and blue forces is similar in that the time to detect is fixed at a given interval of thirty seconds. If it takes longer than 30 seconds to detect an opposing element, then that element is not detected. This concept is explored in more detail later in the chapter. The detection modules also serve to allocate the unit's fire, assigning targets to those elements who have detected them. The fire module is stochastically based, using probabilities of hit and kill given hit in a Monte Carlo model to determine the outcome of an engagement. If a hit on a target does occur, the model determines either a kill or no/unimportant damage to the vehicle. Once a vehicle has been killed it is removed from the simulation, no longer able to either provide additional maneuver or fire, nor can it be detected by the opposing forces.

Within the movement phase is the minefield logic. The module deals with a minefield in two phases, that of actions taken upon entry into a minefield and casualties due to entry, and actions taken during the breaching or bypassing of the minefield. The determination of whether a mine detonation occurs, the exact location of the detonation and the damage incurred is a function of the density of mines in the field, the effective vehicle width and the actual distance traveled in the minefield. Knowledge about the specific location of a minefield is

gained in one of two ways, either by visual detection of the minefield prior to entry or by detonation of a mine after entry. Options based on minefield knowledge are discussed in a subsequent section. The mines are considered to be either surface laid or buried. Two minefields are modelled in the simulation, one emplaced far (approximately 3000 meters) from the objective and one emplaced near (approximately 1500 meters) the objective. The probability of detection for the far minefield is low due to the assumption of no reinforcing obstacles or readily identifiable boundaries. The near minefield's detection probability is set higher due to the likelihood of reinforcing the field with wire obstacles. The detection probabilities are, however, input data and may be changed to conduct additional analysis. Battle termination stops the simulation when either of the following criteria is met:

1. Red force strength falls below 25 percent
2. The minimum range between forces is less than 250 meters.

There are no battle termination criteria used for the blue force other than if a company's strength falls below 50 percent, it assumes a defensive posture.

In addition to the main simulation discussed above, an enhanced simulation was developed based on the concept of limited command, control, and communications (C^3) versus total C^3. The only control in the initial model is to

insure an alignment of forces with respect to the range to the enemy.

In the enhanced model, in addition to the alignment of forces, the presence of minefields in the area of operations is communicated to the rest of the battalion after initial detonation or detection of the first minefield by the lead unit. This concept is discussed in detail in the minefield logic section of this chapter and is the only modification to the initial model. All other subroutines function the same in both models.

A. TACTICAL SCENARIO

The scenario used in the model is based in West Germany on terrain similar to that found near the Fulda Gap. The NATO forces have assumed an offensive posture and the 3rd Battalion, 35th Armor is to conduct a deliberate attack to secure near side crossing sites on the Ulster River on the East-West German border. Although enemy forces in the area have been weakened by the past days of fighting, front line troops are in prepared defensive positions protecting the crossing sites. The enemy is believed to be in an economy of force posture and has used reinforcing obstacles to strengthen its position. Reconnaissance by the Scout Platoon has been unable to provide enough information about possible minefields or gaps in the defending system, therefore the decision has been made to breach into and through the defending system in all cases except when

breaching assets are not available. The enemy force is believed to consist of a tank company of T-72s reinforced by a platoon of BMPs occupying prepared defensive positions (Figure 3).

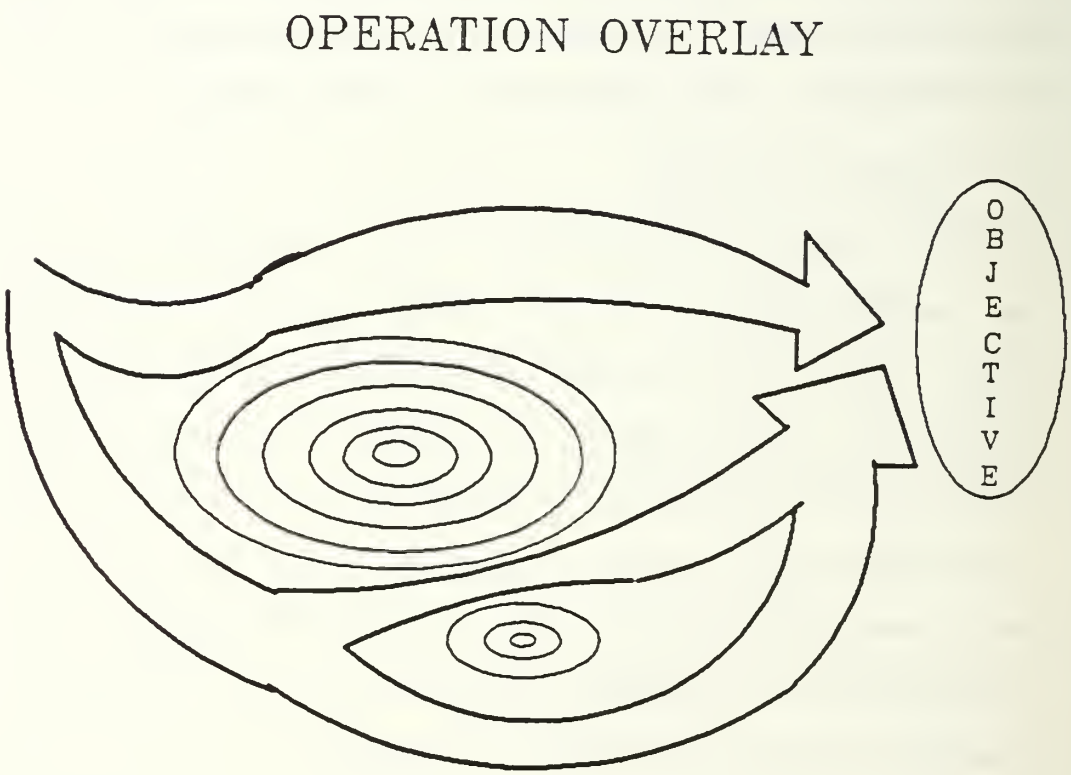


Figure 3. Operation Overlay

A quick attack is to be made by 3-35 Armor along twin axis of advance with selected limited objectives (Figure 3). The battalion will attack with two companies abreast on each of the two axis to secure the high ground on the objective currently held by the red forces.

B. INITIALIZATION AND DATA INPUT

There are fourteen data files which provide support to the simulation. These files support the movement network, the detection/fire modules, and the unit formation and breaching routines and are listed in Appendix C.

Data files 1 through 4 support the movement network by providing arc and node designators, locations of nodes, distances and headings of the arcs, speeds that the unit can maintained based upon terrain, equipment and formation, and the axis of advance for each of the four maneuver units.

Data files 8 through 11 delineate the four possible formations the blue forces are able to use in the conduct of the attack. Figure 4 shows the four formations. Formation configuration and vehicle placement are changed simply by changing the x and y offset positions from the control or ghost vehicle. The purpose of the control vehicle is described in the movement module.

In both versions of the model, formation 0 is used when a unit assumes a defensive posture; formation 2 is the

formation used during the breach or bypass of an obstacle. Formation 1 is the movement/assault formation used by the unit at all other times in model 1. In the enhanced model formation 1 is used by all units until the first minefield is detected/detonated. Formation 3 is then assumed as the standard movement/assault formation at all times except when the use of formation 0 or 2 is invoked.

There are five vehicle type codes used in the simulation. Vehtype1 is the designator for a basic M1. Vehtype2 is for a mineplow tank with the plow in the raised position. Vehtype4 is the designator for the same type of vehicle, with the plow in the lowered or deployed position. Vehtype3 and Vehtype5 are used in the same fashion for the mineroller tank, 3 being used to designate the roller in the raised position and 5 to designate the roller in the deployed position. Both the mineroller tank and the mineplow tank can become a regular M1 tank if the breaching attachment is destroyed during conduct of the battle. Therefore it is possible to begin the battle with 10 tanks, 2 mineplow tanks and 2 mineroller tanks and end the battle with 14 regular tanks, if all the attachments were destroyed during breaching operations.

Data file 14 places the blue elements in specific positions outlined in the various formations (Figure 4). For example, if a unit consisted of 14 vehicles (10 tanks, 1 mineroller tank and 3 mineplow tanks) the entry order of

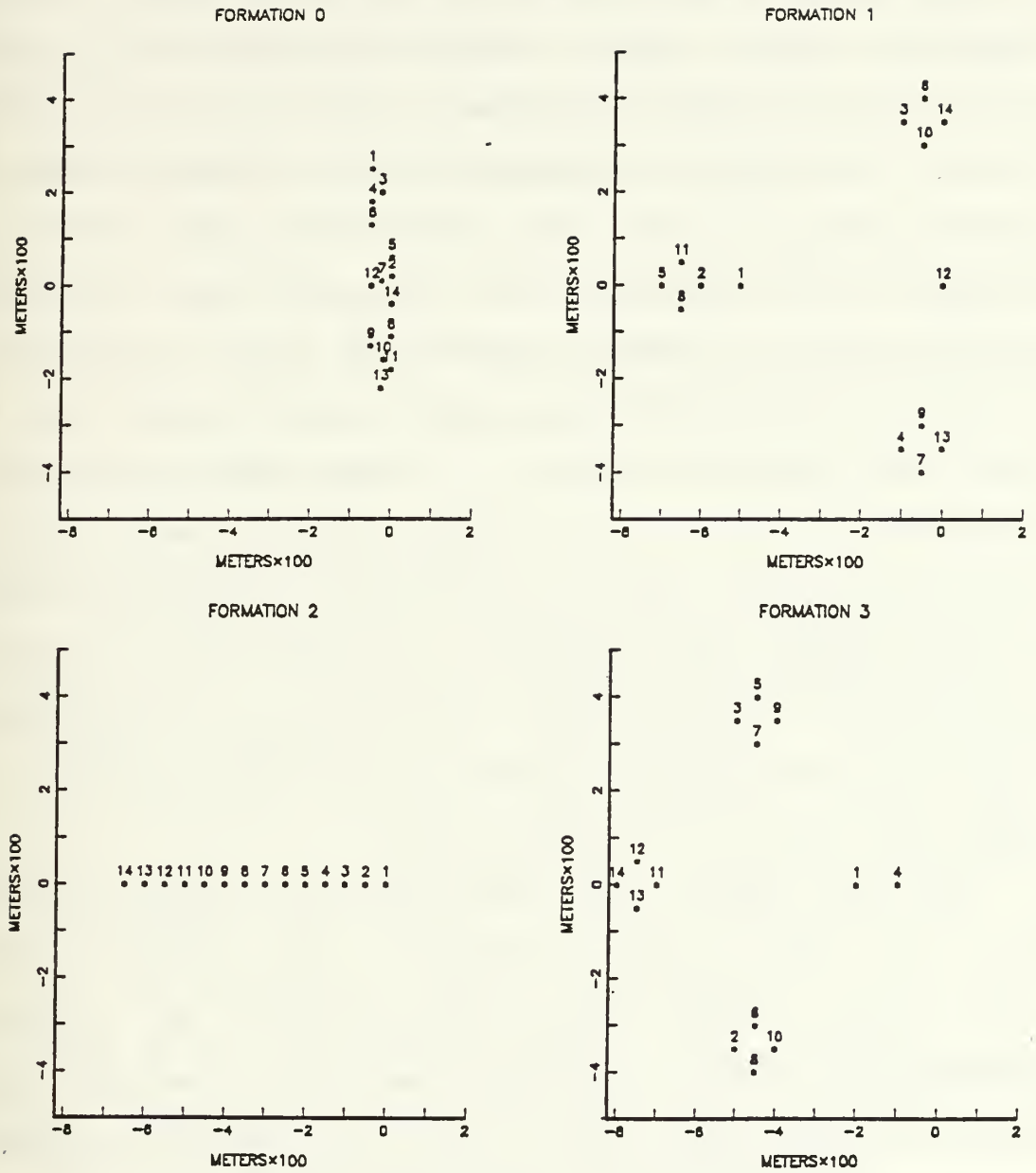


Figure 4. Unit Formations

the vehtype code into data file 14 is the position they would occupy in each of the formations. Therefore if the mineroller tank is entered first as vehicle type 3 in the file, it would occupy the number 1 position in each of the various formations, a mineplow tank entered second as vehicle type 2 in the file would occupy the number 2 position in all formations, etc. This obviously allows the configuration, in terms of numbers and types of equipment, of each unit independently as well as allowing each unit to place that equipment wherever it wishes within each of the formations. The only restriction regarding unit size is that they all must have the same number of total vehicles and that number cannot exceed 20 vehicles without changing the dimensions in the program. For example, one unit could have all tanks while another could have 10 tanks, 3 mineroller tanks and 1 mineplow tank.

The only vehicle type codes that are entered by the user are one, two, or three. The program will automatically change vehicle type 2 and 3 to 4 and 5 appropriately during breaching operations, changing them back to vehicle type 2 and 3 once the breaching operation in that particular unit has been completed.

Data files 12, 13, 15 and 16 support the red forces in such areas as position (file 12), the probability of looking in a particular direction (file 13), the vehicle type, height, and maximum engagement ranges (file 15) and

finally the probabilities of hitting a target and killing the target given a hit, which obviously support the detection and fire modules. Data file 17 provides the probabilities of hit and kill for the blue forces in the same manner as file 16 for the red forces.

In addition to the data files, there are several initial data statements in the program which support the minefield setup module with minefield depths, densities, and probabilities of occurrence, all of which may easily be changed by the user.

C. MINEFIELD SETUP MODULE

The anti-vehicular minefield is represented in the simulation as a uniform distribution of mines which are randomly dispersed within the minefield. The minefields are modeled as continuous with the depths ranging from 150 to 300 meters for the minefields located at approximately 3000 meters from the enemy position and 200 to 300 meters for the minefields located approximately 1500 meters in front of the red force position. The minefield densities are expressed in terms of mines per square meter rather than the standard mines per meter of frontage.

Because the fields in this simulation have only a depth associated with them, this unit of measure for density is preferred. The density of the far field is .003 mines per square meter and the density of the near field is .02 mines per square meter. The densities and depths of the

minefields can be easily changed by changing the data statements at the beginning of the simulation. By setting the maximum and minimum depths of the minefields equal, all fields will be of the same depth. The depth of each minefield is determined by a uniform (0,1) random draw which then determines the field dimension by

Depth of Minefield

=mindepth + ((maxdepth-mindepth)*U(0,1)) / 1000

(equation 3.1)

The basic concept of the minefield effects calculation is that of the expected distance to a mine encounter. Since the mines are randomly placed, the expected distance to the initial encounter and then each succeeding encounter is exponentially distributed. Therefore the expected distance to a mine encounter given by equation 3.2.

E[distance to encounter]=ln(1-U(0,1))/(-width*density)

(equation 3.2)

where the width is the effective width of the vehicle encountering the mine and the density is the density of the minefield in which the encounter is taking place. Successive distances to each encounter are thus calculated prior to the commencement of the simulation and are stored for future use.

One other feature which is included in the Minefield Setup module is the probability that a particular minefield

is actually emplaced. In the simulation, runs were evaluated under a worse case scenario and a most likely or average case scenario. The most likely or average case scenario used a 70 percent chance of each of the far minefields being in place and a 90 percent chance of each of the near minefields being in place. Therefore the possibly exists on any single run for anywhere from zero to eight minefields to be in place facing the blue force, and on any single avenue from zero to two minefields to be in place, based on the random number draws. By emplacing the minefields in this fashion and then running multiple repetitions of the simulation, a long run average minefield emplacement will be achieved providing a greater degree of variability in the evaluation of the likelihood of success of a particular unit configuration.

D. UNIT STATUS MODULE

The unit status module serves to keep a running total on the losses of equipment by unit and type. It is in this routine that the determination of whether a unit goes to a defensive posture is made. If the unit is less than 50 percent effective (i.e., it has lost over half of its equipment), then it assumes a defensive posture, thereby decreasing the likelihood of acquisition by moving to a hull down position. This aspect will be discussed in more detail in the Red Detect module. When a unit goes to a

stationary defensive posture, there is no impact on the speeds of the remaining units.

E. UNIT LOCATION MODULE

The unit location module exerts command and control over the battalion by delaying units which are moving too fast. The ranges to the enemy force of all four blue units will be in the interval [rngmin,rngmax] where the two limits are determined by the unit closest to the enemy force (rngmin) and the unit farthest from the enemy force (rngmax).

The module computes the range to the objective of each unit. If the range difference between all the units is less than 500 meters, then all units proceed at the maximum speed possible as determined by terrain and equipment in each unit. However, if the range difference between the closest and farthest units is greater than 500 meters, then the speed of the closest unit is adjusted downward by a lag factor, AAA. The factor AAA is computed by equation 3.3:

AAA=(rngmax-rngmin)/lag

(equation 3.3)

where lag is the maximum distance allowed between the closest and farthest units: in this case, 500 meters. This value is then passed to the movement module where it is used to decrease the speed of the leading unit. As an example, if the range of the closest unit is 2.4 kilometers

and that of the farthest unit is 3.2 kilometers, then the value of AAA would be:

$$AAA = (3.2-2.4)/.5 = 1.6$$

This value is then used to decrease the speed of the leading unit by a factor of 1.6. Thus for a speed of 25 kilometers per hour decreased by an AAA of 1.6, the new speed of the unit would be 15.625 kilometers per hour.

F. MOVEMENT MODULE

The movement logic is first discussed in detail without the minefield modules included. Minefield tactics and how they impact on the movement routine are discussed in the following section. The Movement module is made up of three distinct routines; a determination of unit speed, location and distance traveled along an arc, and the location of each of the elements in the unit in x and y coordinates (Figure 5).

Unit movement consists of moving each unit along a network of arcs, each of which has a distance, heading and speed associated with it. The network used to support this simulation is shown in Figure 6. A unit starts at the tail node of the arc, moving as far as possible in the 30 second time interval, based on the allowable speed associated with that particular arc and the type of equipment in the unit. For each 30 second time step the following process is followed for each unit in the Movement module. On entry into the subroutine the first decision is whether or not

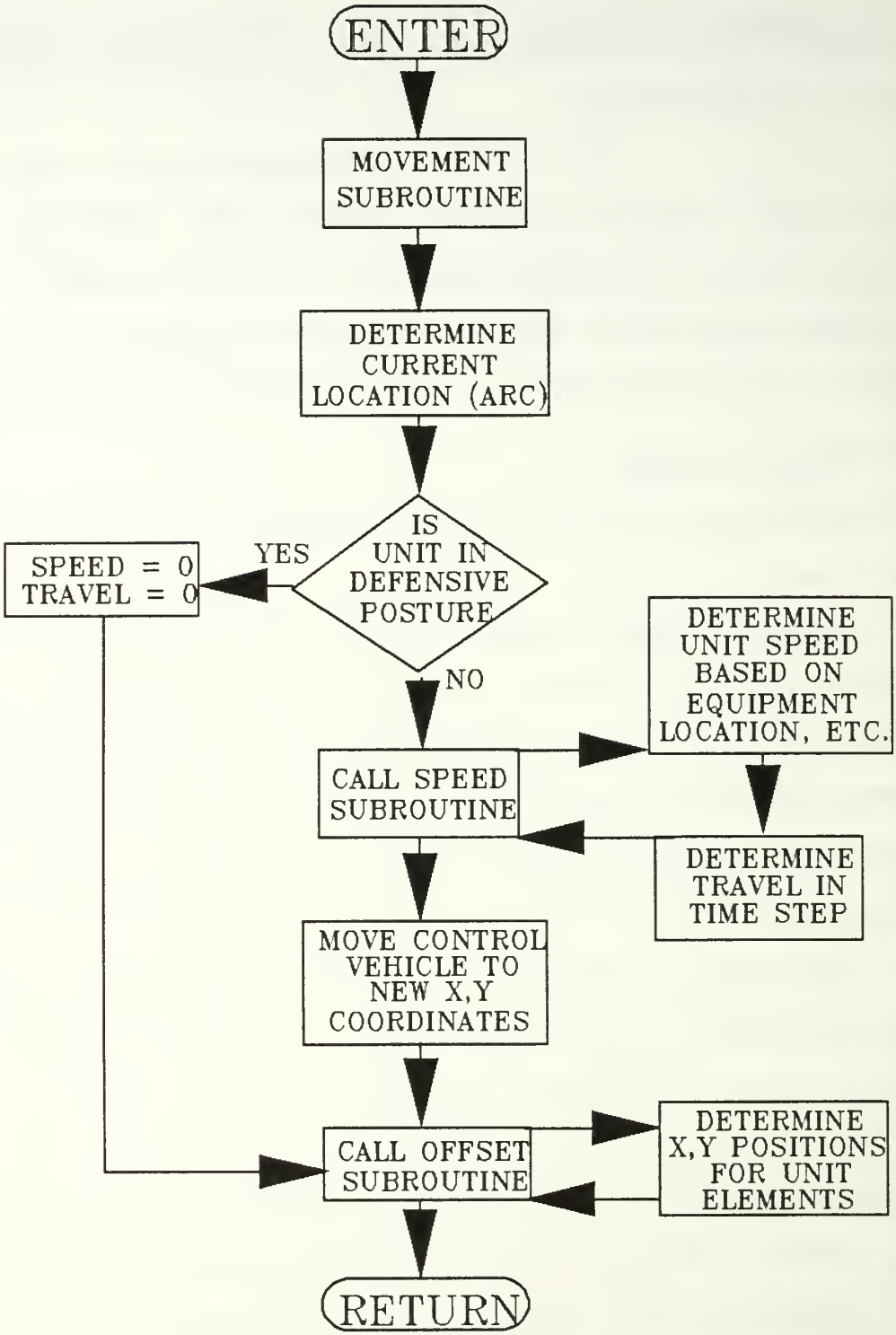


Figure 5. Movement Flowchart

the unit is in a defensive posture. If it is, then the unit speed is set to zero and the logic loops to the offset routine where the x,y position of each element is determined.

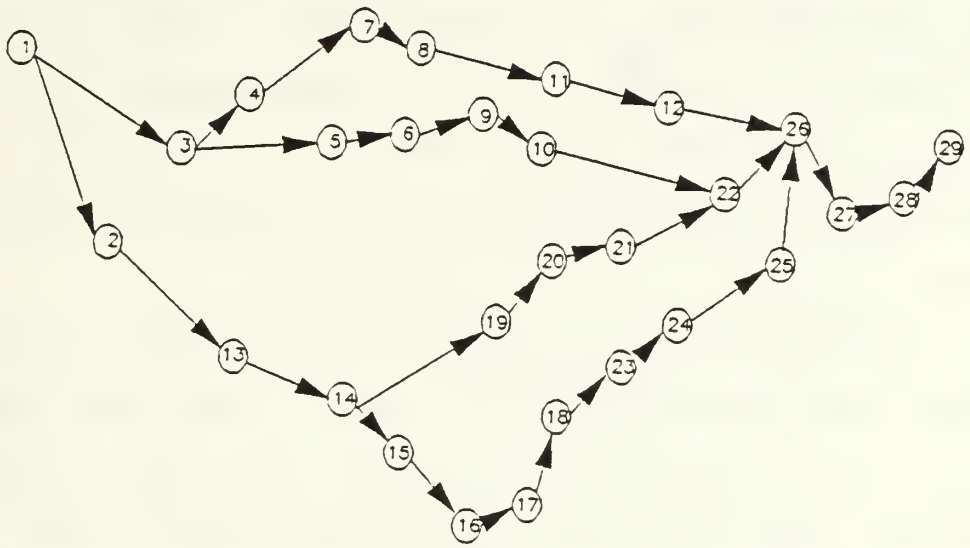


Figure 6. Network Supporting Movement Routine

If the unit is still combat effective the Speed subroutine is entered to determine the unit's speed and travel. The first step is to determine the maximum speed a unit can maintain on a given arc based on equipment in the unit and terrain characteristics for that arc. The trafficability and slope of the terrain are taken into account by degradation of the unit speed as shown in the Speed file (Appendix C).

If the unit has a mineroller tank, then that vehicle is the limiting speed factor unless the unit also has mineplow

tank which is currently being employed, in which case that vehicle is the limiting speed factor. The speed of a unit may vary on a single arc as the unit's equipment changes configuration or is attritted. Once the speed of the unit is determined, if it is the unit closest to the enemy and the lag factor, AAA, is greater than 1, then the speed is decreased accordingly. Once the final speed for the time step is determined, the travel for the thirty second interval is determined and control returns to the Movement module.

The ghost vehicle is the only vehicle that is actually moved and controlled by the model. Once the speed and travel of the unit is determined, the ghost vehicle is moved to a new set of x,y coordinates along the arc. Then, depending on the current formation of the unit, the elements are positioned by the Offset subroutine. The new positions are determined by the x and y offset distances obtained from the appropriate formation data file and are adjusted depending on the current heading of the ghost vehicle along the arc (Figure 7).

As an example, an element that is offset (-1.0,1.0) is 100 meters up and 100 meters behind the ghost vehicle. If the current position of the ghost vehicle is (483,621) and it's heading is due east then the element is located at (482,622). If, however, the ghost vehicle was at the same

location but heading northeast (45 degrees from the x axis), then the location of the element is (483.0,619.6).

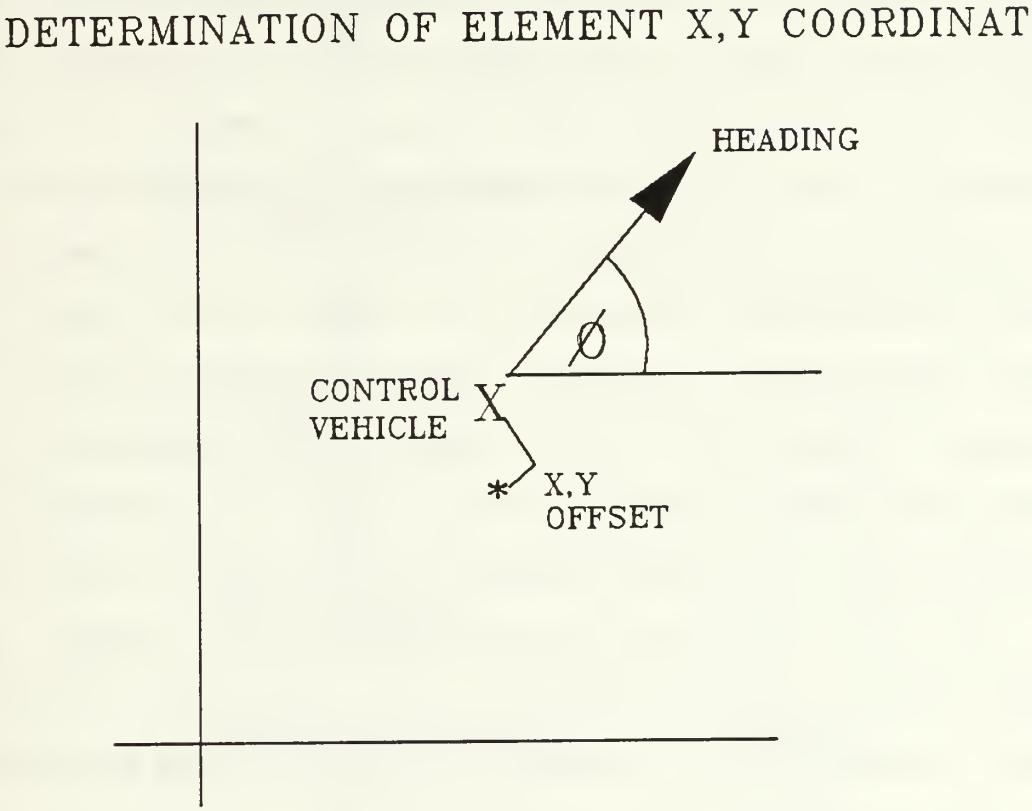


Figure 7. Determination of Element X,Y Coordinates

When the unit reaches the end of an arc, the unit assumes the new heading and speed associated with the next arc in the network. In this fashion, all units are able to move independently over any network which may be developed to support the scheme of maneuver.

G. MINEFIELD LOGIC

Once the Movement routine was developed, it was a simple matter to construct and insert the minefield logic which is the heart of the simulation. The minefield logic, like the rest of the simulation, is flexible in nature, allowing for an unlimited number of configurations. Minefields may be placed on any arc in the network, the only restrictions being that the arc must be longer than the depth of the minefield and only two minefields per avenue of approach may be input. The probability of a minefield being in place, the density of the minefield and the maximum and minimum depths are all input by the user.

The minefield logic is discussed in two phases: first the actions taken on entry into the minefield, and second, the actions occurring during the breach of the minefield.

H. INITIAL ENTRY INTO A MINEFIELD

A decision model has been developed which represents the process by which a unit commander selects one of the three possible options available to him when a vehicle in his unit detonates a mine or the location of the minefield is detected visually. Figure 8 shows the general sequence of events involved in the minefield detection logic. As discussed earlier, he may choose to:

1. conduct a hasty breach if the unit possesses any breaching equipment;

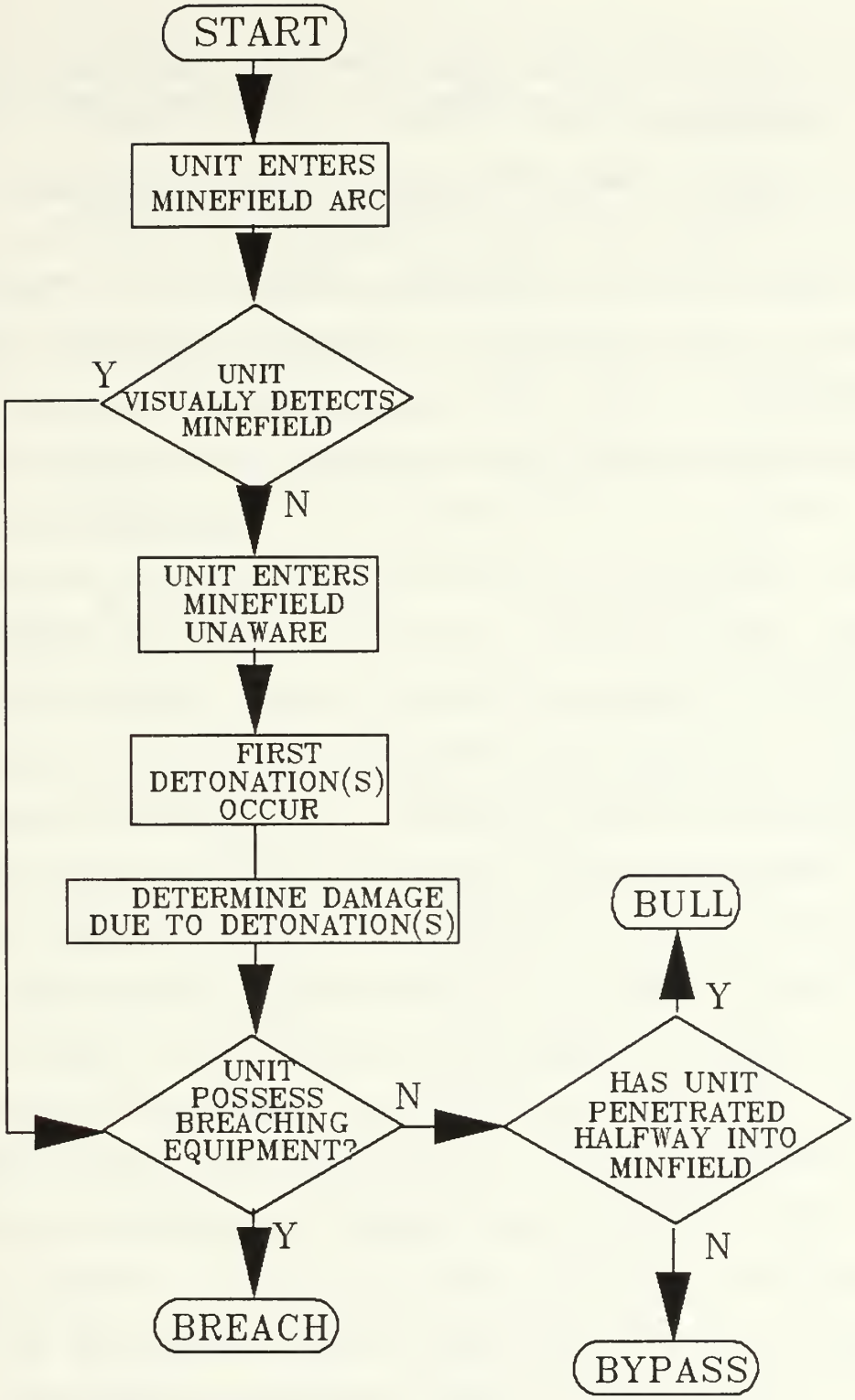


Figure 8. Minefield Logic Flowchart

2. bypass the minefield if the tactical situation permits or he does not possess any breaching equipment; or

3. order a "bull through", hoping to clear a lane without sustaining overwhelming casualties.

The choice the commander makes in the simulation is based on the knowledge he currently possesses about the minefield. Once that knowledge about a particular minefield is gained, it is assumed to be perfect knowledge in regards to the boundaries of the minefield and the unit's location within that minefield. If the knowledge about the minefield is gained prior to entering the minefield, then the model will elect one of two options; either a breaching operation if the unit currently possesses breaching equipment, or a bypass if it does not. The breaching operation begins at the edge of the field and distances to mine encounters are retrieved from the array previously calculated in the minefield setup module.

If the knowledge about a minefield is gained after entry, it is gained the hard way by detonation of a mine. The simulation is able to react in one of three ways. If the unit possesses any breaching equipment, it begins a breaching operation from the point where the mine detonation took place, since it is assumed that up to that point the minefield has been successfully breached. If the unit does not possess any breaching equipment, the decision to "bull through" or bypass is based on the distance into the minefield that the detonation took place, thereby

assuming perfect knowledge for the commander on the specific boundaries of the minefield once it is identified. If the detonation occurred less than half way through the minefield, the unit commander elects to conduct a bypass operation. If the unit has penetrated more than half way through the minefield prior to the first detonation, then the unit will "bull through" the minefield, hoping to minimize losses as compared with attempting to back out and bypass the obstacle.

In all cases, regardless of the option chosen by the unit, the following two actions occur. The unit is assessed a thirty second delay in movement while changing formations and any enemy elements which have been detected by the unit entering the minefield are lost. Therefore, if in the period (t,t+30) the unit had detected an enemy element, during the normal sequence of events that element would have been engaged during the period (t+30,t+60). However, due to the minefield encounter occurring during the period (t+30,t+60), all detections are lost and all elements in the unit entering the minefield must reenter the detection module during the period (t+30,t+60). Additionally, at any time the unit is in a breaching operation all vehicle types 2 and 3, which are now coded as 4 and 5, respectively, cannot conduct direct fire engagements. This restriction occurs because the crew is

occupied with the conduct of the breach as opposed to trying to detect the enemy.

I. BREACHING OPERATIONS

If a minefield has been entered, the breaching operation commences. Although the bypass is not really a breach of the obstacle, it does allow the unit to circumvent the minefield and continue its mission.

In the simulation the bypass option is dealt with rather simply. Rather than building additional arcs and nodes as a bypass route, which would invariably restrict the placement of minefields, the unit's speed is simply degraded and the mine detonation routine is suppressed. In this manner the unit is subjected to enemy fires for a longer period of time and the delay in forward progress accurately simulates the requirement to move parallel to the minefield in hopes of discovering a route around the obstacle.

A similar methodology is used for the "bulling thru" technique. The unit, in it's attempt to "bull thru", maintains a single column formation, thereby reducing the exposure of trailing elements to mine detonations.

The formation the unit uses while breaching the minefield is specified as input to the model. In this simulation, the formation used in all breaching operations is a single column of vehicles with all the breaching assets at the head of the column.

The unit will conduct the breach if it possesses the requisite assets. The simulation places all the breaching equipment at the front of the formation, with all the mineplows leading, followed by the minerollers, then followed by the remaining vehicles in the unit. The order that the vehicles enter and breach the obstacle is user input through the use of formation 2. The simulation does allow for a breaching device to be destroyed without destroying the carrier on which it is mounted. If a breaching device does become inoperable, then that vehicle's type code is changed to a 1 (M1 tank) and it is cycled to the rear of the formation. In this fashion, a vehicle with no breaching device does not lead the breach (unless there are no more breaching assets in the unit).

The simulation will allow any of the following cases to occur depending on the random draw.

1. A clearing device may be destroyed.
2. The carrier of a breaching device may be destroyed.
3. A mine may be left uncleared.

In case 3 a following vehicle may clear the mine if it has a breaching device, or it may detonate the mine and be killed.

In the breaching logic, mine encounters by each type of vehicle are dealt with in the following manner. If a vehicle type 1 encounters a mine, a random draw is conducted to determine a kill or no/unimportant damage.

For the M1, all mines are detonated when encountered and none are left uncleared under the tracks.

If the lead vehicle is a mineroller, there is a two step process in the determination of the probability of clearing and surviving the mine encounter. Figure 9 shows the process for the clearing of mines by the mineroller tank. When a mine is encountered there exists a probability associated with the clearing of the mine and, then given the clearing (by detonation with the rollers), a probability associated with surviving the blast.

Although the operation is similar for the mineplow, a mine encounter involves a three step process to determine the outcome of an encounter. Figure 10 shows the methodology used for an encounter by a mineplow tank. There is

1. a probability associated with clearing the mine,
2. a probability of detonation given the plow cleared the mine and finally
3. a probability of surviving, given the detonation by a cleared mine.

If a unit has breaching assets, then it conducts a breach. However, after losing its last piece of breaching equipment the decision to "bull thru" or bypass is the same as when the field is first encountered. If the unit has not penetrated at least halfway through the minefield, then it conducts a bypass. If it has reached the halfway mark,

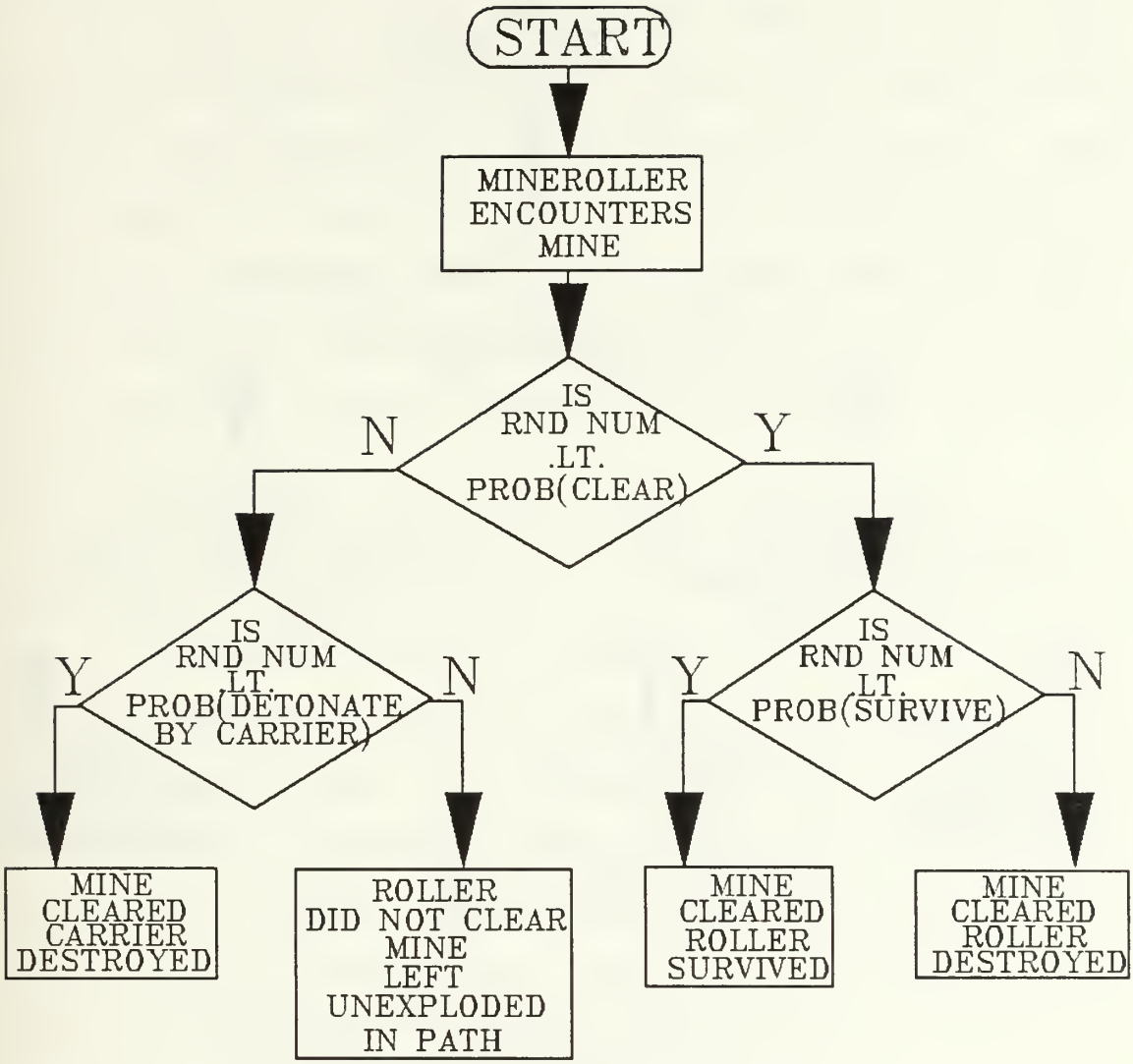


Figure 9. Mineroller Breaching Flowchart

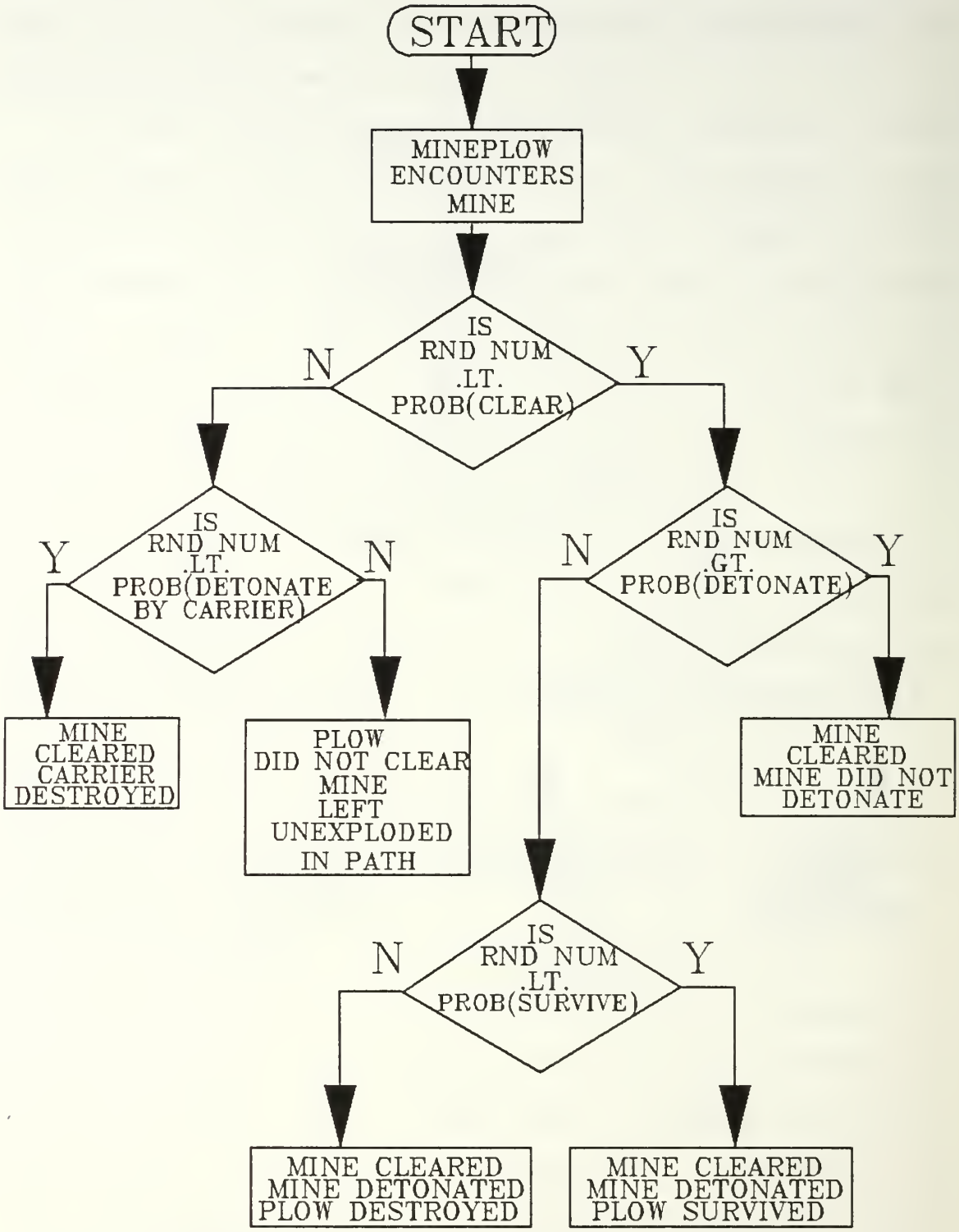


Figure 10. Mineplow Breaching Flowchart

then the unit will "bull" the rest of the way through the minefield.

In Model 1, units encounter and deal with each minefield entirely on their own. There is no communication between units regarding the encounter of a minefield. Each unit stays in formation 1 until they either detect or detonate a minefield, suffering the losses associated with each encounter. Once the field is cleared the unit returns to formation 1, and the process is repeated for the second minefield.

With Model 2, communication regarding minefield locations is simulated. When the lead unit encounters the first minefield, all the other units in the battalion assume a detection formation. Formation 3 in Figure 4 is used for this purpose. The mineroller tank is placed in the lead in hopes of detecting the location of the minefield on the axis of advance by the rollers and avoiding vehicle losses due to detonations. Additionally, when the unit exits the minefield, it resumes formation 3, as opposed to Model 1 where the unit assumes formation 1.

Once a unit has successfully breached a minefield, vehicles in that unit are not subject to mine detonation since the clearing operation is assume to be completely effective. Prior to that point, mines that were not cleared by a breaching vehicle may detonate and cause casualties to following elements.

J. FIRE AND DETECTION MODULES

The Fire and Detection modules operate simultaneously in the model. It is possible for different elements of the same unit to be detecting or firing during the same 30 second time period. The model does not restrict the unit to either the detection or firing phase during each time step. All elements initially start out in the detection mode. When element i detects an opposing element j during the period (t,t+30) then during the following period (t+30,t+60) element i enters the firing module and conducts the engagement. If the detection of element j occurred during the period (t,t+30) then during the following 30 second time period line of sight is assumed to continue to exist for the firing phase. It is also assumed that if element i is busy firing during the period (t,t+30) then no target search is conducted by element i during this time interval.

The red forces may detect or engage , depending on the type of vehicle, up to two enemy elements in the thirty second time period due to their stationary defensive posture. Tanks can detect or engage two elements in the thirty second period while a BMP is able to either detect or engage only one target during the time interval due to the characteristics of the weapon system.

The blue forces, due to their offensive posture, are able to detect or engage only one enemy element in a time

period. As a control for fire distribution only 2 red elements may detect or engage any single blue element at a time while 4 blue elements may detect/engage any single red element at a time.

Once a firer has completed his direct fire engagement(s), he returns to the Detect module during the next time period regardless of the outcome of the direct fire engagement. Even if during the period (t,t+30) element j engaged but did not kill element i, he must still go back to the Detection module during the next time step and attempt to redetect element i.

K. DETECTION MODULE

The Detection modules for the red and blue forces are exactly the same except for minor differences which will be pointed out in the discussion as they occur. Figure 11 shows the flow through the red Detection module. The only difference in the flow through the blue Detection module is that the red forces are always in a defensive posture, therefore there is no need for crossing velocity calculations.

The detection computations used in the simulation were adapted from the DYNTACS model with some minor changes. [Ref. 12] For each element i the computations look at every enemy entity in the thirty second period to determine if they can be detected. A detection rate, DETRATE, for

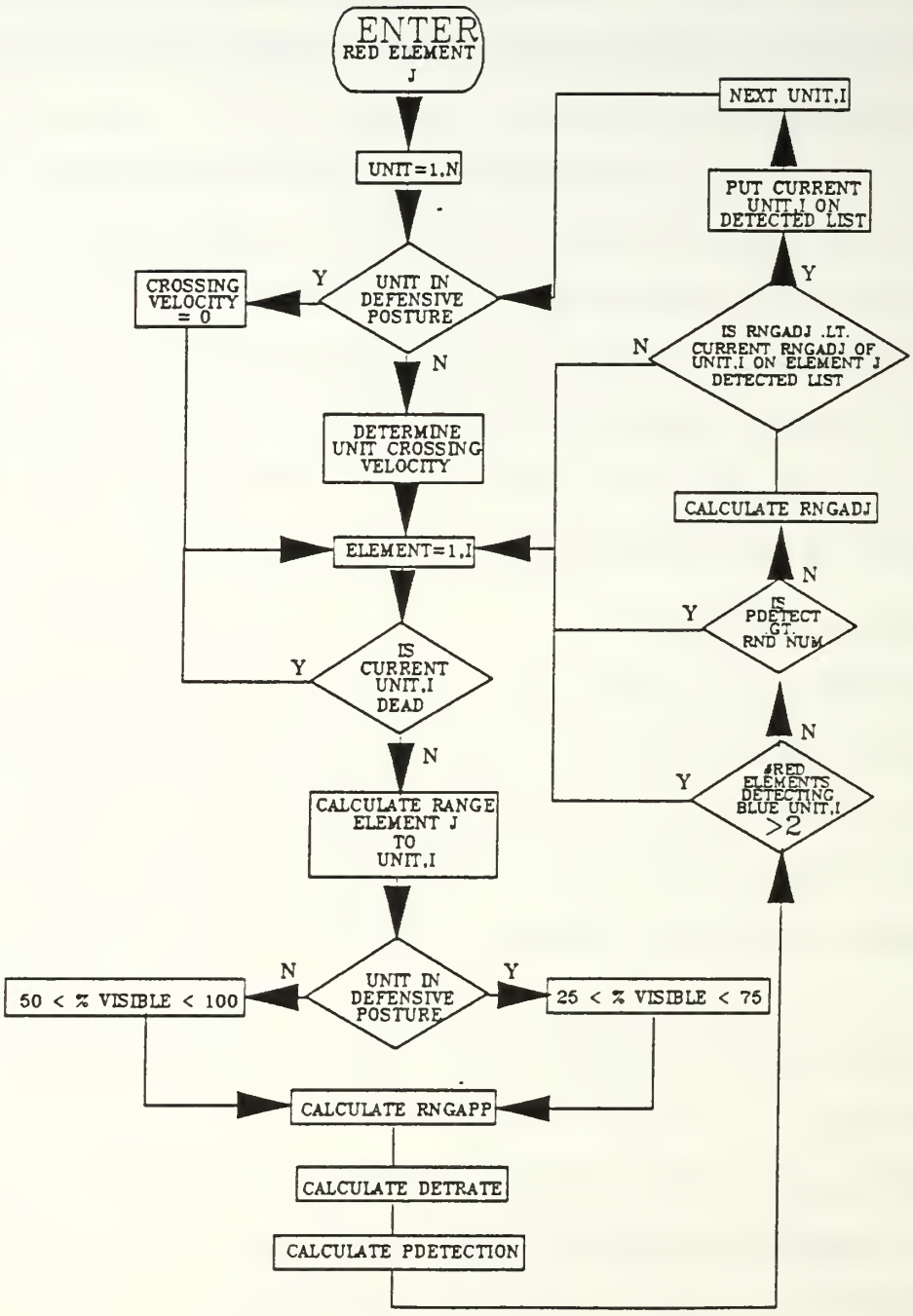


Figure 11. Red Detection Flowchart

every enemy element is computed is assumed to be constant for at least 30 seconds. Then the continuous looking model is used to compute the probability of detection in equation 3.4.

$$REDPDET = 1 - \exp(-DETRATE * T)$$

(equation 3.4)

where T equals 30 seconds. Finally a Bernoulli trial is performed to determine whether or not the target is detected.

The detection rate equation 3.5 DETRATE is:

$$DETRATE = RPLOOK * (-0.003 + [1.088 / DENOM])$$

(equation 3.5)

where:

$$DENOM = 1.453 + (TAU * (0.05978 + 2.188 * RNGAPP * RNGAPP) - 0.0538 * CV)$$

and where the observation conditions are described by:

TAU = terrain complexity code; it can take on values from 1 to 7

RNGAPP = apparent range in kilometers. The apparent range is the range at which a fully exposed M60 tank would present an image which is the same height as the image that is observed for the current target. RNGAPP is computed as:

$$RNGAPP = (\text{actual range} * \text{M60 height})/(\text{target height} * \text{percent visible})$$

where the denominator in the simulation is a random variable. For the attacking blue force, the percent

visible ranges from 50 to 100 percent for an offensive posture and from 50 to 75 percent for those unit which have assumed a defensive posture. For the red force the percent visible ranges from 25 to 50 percent due to the availability of prepared defensive positions.

The crossing velocity (CV) is measured in meters per second and is the target velocity component which is perpendicular to the target-observer line. It is the component of target movement which is most noticeable to an observer. The crossing velocity for the red force is zero, since they are in stationary defensive positions. When a blue force goes to a defensive posture, the model also sets their crossing velocity component to zero.

RPLOOK is the probability that the observer is looking in the direction of the target and is a user input in the model. For the blue force it is a constant 75 percent chance of looking in the direction of the target and for the red force it is dependent on the avenue of approach.

L. DIRECT FIRE MODULE

The Direct Fire module is stochastically based using probabilities in a Monte Carlo model to determine the outcome of an engagement. The range from the firer to the target is calculated and then used in a table look-up to determine the probability of a hit and of a kill given a hit. The values are then compared to a random draw to determine the outcome of the engagement. The only outcomes

are either a kill or no/unimportant damage. If a target is killed it is assigned a "dead" code and is removed from the simulation.

This completes all the necessary modules required to conduct the battle simulation to generate the data necessary to analyze the measures of effectiveness developed in Chapter 2. The output is analyzed and the MOEs are evaluated in Chapter 4.

IV. OUTPUT ANALYSIS

A. BASIC RESULTS

The purpose of the simulation is to generate output to be used in the analysis of measures of effectiveness (MOEs). In this section numerical results are presented for each configuration and scenario. Fifty repetitions of each configuration were conducted and there were 5 different configurations evaluated against four different scenarios. The output provides a performance evaluation prediction of the mine countermeasures equipment. The four scenarios allow for the MOEs to be evaluated under varying conditions.

Scenario 1 evaluates the unit's performance when facing only direct fire weapons. The purpose of this scenario is to determine the impact of the countermine equipment on the unit's ability to fight when no obstacles are present. Scenarios 2 and 3 evaluate the unit's performance when faced by a combination of direct fire weapons and minefields. Scenario 2 examines the situation where there is a probability that the minefields are emplaced; Scenario 3 looks at the worse case situation: the probability of the minefields being in place is equal to 1. Scenario 4 is used to determine the effectiveness of the countermine equipment when faced only with minefields.

Sample data files used to support the evaluation of the MOEs are shown in Tables 1 and 2 (all tables and figures follow this chapter). In the heading of Table 1, the starting force configuration is shown. Columns 1 through 4 tabulate the direct fire losses by repetition. Column 1 is the total number of losses, column 2 is the direct fire losses of the M1, column 3 is the direct fire losses to the mineplow tanks and column 4 is the direct fire losses to the mineroller tanks.

Columns 5 and 6 of Table 1 give the losses of the breaching device due to mine detonations. Columns 7 through 10 represent the losses to the force due to mine detonations, each column representing the equipment in the same order as for the direct fire losses. Columns 9 and 10 represent the losses of the mineplow and mineroller tanks when they are not in a breach mode, i.e., the breaching device was not employed at the time of detonation.

Columns 11 and 12 represent the losses of the mineplow tank and mineroller tank due to mine detonations while attempting to breach the minefield. Column 13 is the total number of kills due to both direct fire and mine detonations and is the summation of columns 1,7,11 and 12. Column 14 is the length of the battle while column 15 is the minimum range attained by any unit during the battle.

Table 2 gives the status of the minefields on each axis and the time a unit went to a defensive posture. Columns

M1 (far minefield) and M2 (near minefield) give the status of the minefield, a 1 representing an active field while a 0 represents an inactive field. The time to defensive posture is given for each unit, a time of 0.0 meaning the unit did not assume the defense. The last column is the time to battle termination and is the same as column 14 in Table 1.

Tables 3,4,5 and 6 show the results of the evaluation of the output as derived from the MOEs. The sample mean is given, followed by the sample standard deviation in parentheses. Each column is the evaluation of a particular configuration against all applicable MOEs. Obviously in some cases an MOE does not apply due to a quantity required not being available, such as the number of pieces of breaching equipment in the unit configuration 14/0/0.

B. EVALUATION OF MOEs

MOEs 1 (Figure 12), 2 (Figure 13) and 3 (Figure 14) all deal with losses to the blue force versus their starting strength. The value for MOE 1 was found by using column 1, Table 1 divided by 56 to give a percentage of losses due to direct fire. Figure 12 shows the comparison of each configuration under each scenario. Direct fire losses for configuration 14/0/0 are low when no mines are present, but are the highest of any configuration as soon as minefields are introduced into the area of operations. Of interest is the fact that even though the configurations with

breaching equipment have higher direct fire losses than the configuration without breaching equipment, the difference is 3 or 4 percentage points at most.

MOE 2 examines the losses due to mine detonations in Figure 13. Values are found by summing the losses in columns 7,11 and 12 from Table 1, and dividing by the starting strength of the battalion. Intuition would dictate that the losses to the force with no breaching equipment would be higher than those configurations with breaching equipment. This is not the case. Since each unit acts independently to detect minefields and the formation used does not place the breaching equipment in the lead, losses due to initial entry into a minefield should be the same for all force structures. It is at this point that the casualties due to mines increase for the forces with breaching equipment. The unit with no breaching equipment will usually bypass the minefields and therefore sustain no further mine casualties, while the units with breaching equipment conducts a breach, losing more equipment to mines in the process.

MOE 3 compares the losses to each unit due to both mines and direct fire in Figure 14. The values are found by using column 13 from Table 1 divided by 56. It is interesting to note that in the cases of the probability of minefields with direct fire and 100 percent probability of minefields with direct fire, the 12/1/1 configuration

performed better than the 10/2/2 combination. This is due to the fact that most of the breaching assets in the 12/1/1 configuration are lost during the breach of the far minefield and the unit is able to travel faster in the 2600 to 1500 meter range band, thereby being subjected to the enemy's direct fire weapons for a shorter period. Of the configurations with breaching equipment, the 8/3/3 unit does the best when there is no direct fire.

MOEs 4,5 and 6 compare the losses of equipment versus the number of pieces of breaching equipment available in the unit. Their values are computed in the same manner as MOEs 1,2 and 3 except the denominator is the number of pieces of breaching equipment. Due to a changing denominator, the comparison of the of the various configurations is difficult. However the MOEs show the increasing number of casualties as the probability of the minefields increase (Figure 15). The synergistic effect of the combination of direct fire and minefields is clearly evident (Figure 16). The losses to any of the forces is the lowest when faced by direct fire only, increasing slightly when faced by minefields only, and increasing drastically when the combination of the two systems interact to defeat the enemy (Figure 17).

Since the number of pieces of breaching equipment are the same in the 10/2/2 and the 10/3/1 configurations they may be examined in more detail for these MOEs. The 10/2/2

configuration performed better when the unit was faced by direct fire only or minefields only, however the difference is minimal. When faced with a combination of mines and direct fire, the 10/3/1 configuration fared slightly better in both the number of direct fire casualties per piece of breaching equipment (Figure 16) and the total number of casualties due to mines and direct fire combined (Figure 17).

The number of units going to a defensive posture is shown by MOE 7 (Figure 18). The number is obtained from columns 3,6,9 and 12 from Table 2. In the scenario with direct fire only, the number of units going to defensive posture is relatively the same for all configurations, thereby again substantiating the point that the countermine equipment does not impact a great deal on the unit when it is faced only by direct fire. Even when the units are faced by scenario 2 (probability of minefields and direct fire) the number of units going to defensive posture does not differ a great deal. It is only when there exists a 100 percent chance of minefields that differences becomes large. The best performer for the configurations with breaching equipment when faced only by minefields is the 8/3/3 combination while the 12/1/1 combination was the worst. However when faced by the probability of minefields and direct fire the number of units going to a defensive posture was significantly lower for the 12/1/1 combination

and even the 10/2/2 combination did better. This can be attributed in part to the fact that the breaching equipment is prevented, by the simulation, from engaging while breaching operations are taking place.

MOE 8 examines the period in the battle when the units went to a defensive posture (Figure 19). The battle was divided into four time periods - beginning, early, middle and late - each period representing one fourth of the duration of the battle. The determination of which period a unit went to a defensive posture was calculated by taking the battle time of each repetition and determining in which quarter the defensive times fell.

Once again all configurations performed equally well when there were no minefields and the units were faced only by direct fire. In this MOE all the configurations with breaching equipment performed better then the 14/0/0 configuration. The 14/0/0 configuration tended to go to a defensive posture much earlier in the battle due to the reduced speed imposed by the bypass routine. The 14/0/0 configuration is able to reach the far set of minefields quicker then the other configurations where it is then stopped and is attritted by the enemy. The configurations with breaching equipment were able to keep moving much longer in the battle, with the 10/2/2 combination performing the best.

The length of the battle is described by MOE 9 (Figure 20). Once again the numbers are misleading unless they are examined closely. In scenario 1, the 14/0/0 unit is able to close with the enemy much sooner (due to no speed degradation caused by the breaching equipment) than the units with breaching equipment. The length of the attack is approximately six kilometers and the higher speeds of the M1 unit allows it to travel faster. Similarly, the probability of minefields combined with direct fire still produced quicker battle times for the 14/0/0 combination, since if at least two units did not encounter the far minefield, they could close rapidly with the enemy and defeat him. The time of battle for 100% minefields and direct fire is essentially equal for all configurations, with the 14/0/0 configuration able to move rapidly between minefields and then losing time while bypassing. The average length of battle when there are only minefields present was approximately the same for all configurations with breaching equipment. It was also approximately the same when each configuration is compared between the two scenarios of 100% minefields/direct fire and when there are only minefields present. The big increase in time occurs in the 14/0/0 configuration, starting from a low in the 0%/direct fire scenario to a maximum in the 100%/no direct fire case. It should be noted that the only battle termination criteria that applies in the 100%/no direct

fire is the minimum range requirement of 250 meters and this requirement causes the 14/0/0 configuration to bypass both the far and near minefields.

The average range at battle termination is MOE 10 (Figure 21). All values are approximately the same with one notable exception, that of the 14/0/0 configuration in the scenario of probability of minefields/ direct fire. This dramatic increase, in relation not only with itself but also with the other configurations, is attributed to the fact that the units on the avenues that are not faced by a minefield move rapidly through the area and suddenly find themselves in a direct fire battle with the enemy where they are attritted to a defensive posture early in the battle. This fact is substantiated by consideration of MOE 8, Figure 19, where the number of units going to a defensive posture in the middle of the battle is substantially higher for the 14/0/0 configuration.

The rate of battle losses is the last MOE. Figure 22 shows the rates which were determined by taking the total number of casualties per repetition (column 13, Table 1) and dividing by the length of battle for the repetition (column 14, Table 1). The figures, when comparing the 14/0/0 configuration with the rest of the configurations, are somewhat misleading. The 14/0/0 had the least number of losses in all cases, but since they are able to travel faster, battle time was shorter, causing the rate to appear

artificially high. Among the configurations with breaching equipment, there is no single best performer, although the 12/1/1 and the 8/3/3 configurations were better than the others.

C. SUMMARY OF RESULTS - MODEL ONE

Upon examination of all the configurations with breaching equipment under the four different scenarios, the best performer was the 12/1/1 combination. The reason is that the breaching assets of the 12/1/1 configuration are, in most cases, just enough to allow the unit to breach through the low density far minefield and then continue the attack without being encumbered by the slow moving breaching equipment. The low amount of breaching equipment also means that the majority of the force is able to engage the enemy while breaching operations are taking place.

The only configuration that clearly performs better than the 12/1/1 configuration is the 8/3/3. This configuration is of greater benefit when there is no direct fire and it is in these situations that the 8/3/3 configuration does perform better.

D. SENSITIVITY ANALYSIS USING THE ENHANCED MODEL

Sensitivity analysis was conducted through the use of the second model. As discussed in Chapter 3, the second model was developed using the concept of perfect communications. When one unit encounters a minefield, the

rest of the units redeploy in formation 3, placing the roller assets in the lead to detect the minefields on their avenue. Two configurations, the 12/1/1 and the 10/2/2, were evaluated under two scenarios, the probability of minefields/direct fire and the 100% minefields/no direct fire, and the output was analyzed under the same MOEs and compared to the values found using Model 1. Table 7 shows the mean and standard deviation of the 50 repetitions conducted under each configuration and scenario.

The two configurations are compared against the base case configuration of 14/0/0. Figure 23 shows the comparison using MOE 1. In both configurations the performance using Model 1 was slightly better. However, using MOE 2, the losses due to mines was greatly reduced using Model 2, even to the point that the 12/1/1 configuration performed better than the 14/0/0 configuration (Figure 24). Figure 25 shows the total percent of losses due to both mines and direct fire. The configurations once again performed better under Model 2, even to the point that the 12/1/1 configuration suffered fewer losses than the 14/0/0 configuration in the probability of minefields/ direct fire scenario.

MOEs 4 (Figure 26), 5 (Figure 27), and 6 (Figure 28) compare the configurations when the amount of breaching equipment is constant. In all four cases the losses per piece of breaching equipment dropped under Model 2, however

there was a slight increase in the direct fire losses. This can be attributed to the fact that once the first minefield is detected, the units move only as fast as the mineroller tank. Overall, the two configurations performed better under Model 2.

The percent of units assuming a defensive posture decreased under both scenarios of the 12/1/1 configuration, but the results were mixed for the 10/2/2 configuration (Figure 29). The period in the battle also showed an improvement for the 12/1/1 configuration under Model 2. In the probability of minefields/direct fire scenario, the number going to a defensive posture in the middle phase of the battle dropped dramatically, with a slight decrease occurring in the late battle also.

Once again the average length of battle figures are deceiving unless examined closely. Figure 31 show an increase in all the battle times. This is entirely due to the fact that once the first minefield is detected/detonated, the fastest speed a unit can move is that of the mineroller tank, at least until it is attritted.

Figure 32 shows the average ending range of the battle with the results indicating little or no difference between the two models. Finally, Figure 33 shows the rate of battle losses, again with a dramatic improvement for Model

2. Obviously the contributing factor is the decrease in losses to the force due to mine encounters.

The tactics used by the attacking force, in particular the method of detecting the obstacles, impacts heavily on the performance of the unit. Under Model 2 the 12/1/1 configuration once again performed better than the 10/2/2 configuration when evaluated under the two scenarios, because the majority of the breaching equipment is lost during the conduct of the first breach and the unit is able to travel faster. Also, under the probability of minefields/direct fire scenario, if one unit detects a minefield and is slowed in its progress, it will be able to easily catch up to the unit that did not encounter a minefield, since that unit is moving only as fast as the employed mineroller tank. This allows the units to align themselves to concentrate their fires on the target.

E. FINAL CONCLUSIONS

Based on the evaluation of the MOEs using the output from both Models 1 and 2 the following observations and conclusions can be made. The amount of breaching equipment required to support an armor battalion is situationally dependent.

The various factors weighing heavily on the required number of breaching assets are the enemy, terrain, mission and tactics. If a battalion is assigned a clearing mission in a lightly defended area, a force configured with a

larger number of breaching assets would perform better, although if time was not crucial and the threat involved was low, a smaller number of breaching assets would prove to be just as effective.

If the area of operations is heavily defended, a force configuration that would allow the unit to breach the outer obstacles and then rapidly close with and defeat the enemy force would call for a smaller number of breaching assets. If the terrain restricts maneuver space to such a degree that the bypass option is no longer viable, the number of assets would have to be increased to insure a greater degree of success.

Based on the configurations and scenarios examined in this thesis, a force structure of 12 tanks, 1 mineplow and 1 mineroller tank is recommended, however further analysis in this area should be conducted to confirm the results.

UNIT 1 UNITCODE 1 EQUIP TANK 10 MINEPLOW 2 0 MINEROLLER 2 0
UNIT 2 UNITCODE 1 EQUIP TANK 10 MINEPLOW 2 0 MINEROLLER 2 0
UNIT 3 UNITCODE 1 EQUIP TANK 10 MINEPLOW 2 0 MINEROLLER 2 0
UNIT 4 UNITCODE 1 EQUIP TANK 10 MINEPLOW 2 0 MINEROLLER 2 0
NUMBER OF KILLS BY CATEGORY PER REPITITION

DIRECTFIRE	ROLL	PLOW	MINEFIELD	PLOWCARR	ROLLCARR	TOTKILL	CLOCK	MINRNG
40/30/ 3/ 7	1	0	5/ 5/ 0/ 0	4	0	49	54.5	1.278
25/20/ 2/ 3	1	0	5/ 5/ 0/ 0	5	2	37	47.5	1.014
15/11/ 1/ 3	2	0	8/ 8/ 0/ 0	2	0	25	41.0	0.803
19/12/ 5/ 2	0	0	0/ 0/ 0/ 0	2	0	21	40.0	1.228
16/11/ 3/ 2	0	0	4/ 4/ 0/ 0	1	0	21	40.5	1.303
20/16/ 2/ 2	3	0	10/10/ 0/ 0	6	0	36	46.5	1.581
17/10/ 1/ 6	1	0	7/ 7/ 0/ 0	2	0	26	42.5	1.588
23/15/ 3/ 5	1	0	2/ 2/ 0/ 0	1	0	26	43.0	0.711
17/14/ 2/ 1	3	0	4/ 4/ 0/ 0	3	0	24	42.0	0.933
27/17/ 4/ 6	2	0	5/ 5/ 0/ 0	4	0	36	49.5	0.877
20/14/ 3/ 3	5	1	16/16/ 0/ 0	4	0	40	46.0	1.414
23/14/ 4/ 5	1	0	3/ 3/ 0/ 0	1	0	27	41.0	2.141
22/14/ 1/ 7	0	0	1/ 1/ 0/ 0	4	1	28	45.5	0.643
23/16/ 3/ 4	1	0	1/ 1/ 0/ 0	1	0	25	44.0	0.651
13/12/ 0/ 1	3	0	1/ 1/ 0/ 0	4	0	18	43.0	1.113
20/17/ 2/ 1	1	0	4/ 4/ 0/ 0	3	2	29	45.0	0.936
9/ 5/ 2/ 2	0	0	1/ 1/ 0/ 0	0	0	10	35.5	1.525
16/12/ 1/ 3	1	0	1/ 1/ 0/ 0	4	1	22	43.0	0.799
15/ 9/ 3/ 3	1	0	5/ 5/ 0/ 0	2	1	23	41.5	1.105
30/24/ 2/ 4	4	1	10/10/ 0/ 0	5	0	45	50.5	0.910
29/19/ 3/ 7	0	0	6/ 6/ 0/ 0	1	0	36	44.0	0.794
20/13/ 3/ 4	1	0	7/ 7/ 0/ 0	2	3	32	48.0	0.937
8/ 6/ 2/ 0	0	0	1/ 1/ 0/ 0	0	0	9	37.5	1.236
28/21/ 3/ 4	2	0	6/ 6/ 0/ 0	3	1	38	47.5	1.005
8/ 7/ 0/ 1	2	2	2/ 2/ 0/ 0	3	0	13	40.5	1.374
31/23/ 3/ 5	1	0	3/ 3/ 0/ 0	3	1	38	49.0	0.889
17/12/ 1/ 4	0	0	3/ 3/ 0/ 0	4	0	24	42.0	1.110
20/17/ 2/ 1	7	1	13/13/ 0/ 0	5	0	38	50.0	0.356
19/13/ 3/ 3	2	0	1/ 1/ 0/ 0	3	1	24	42.0	0.944
14/ 9/ 2/ 3	1	0	4/ 4/ 0/ 0	3	0	21	40.5	1.152
22/15/ 2/ 5	1	0	2/ 2/ 0/ 0	1	0	25	43.0	0.866
20/16/ 1/ 3	3	0	6/ 6/ 0/ 0	7	2	35	49.0	1.101
23/16/ 3/ 4	0	0	3/ 3/ 0/ 0	3	0	29	42.5	1.119
22/14/ 3/ 5	1	0	2/ 2/ 0/ 0	3	1	28	41.5	1.479
9/ 5/ 1/ 3	1	0	1/ 1/ 0/ 0	0	0	10	38.0	1.349
11/ 8/ 2/ 1	0	0	4/ 4/ 0/ 0	0	0	15	42.0	1.009
16/ 9/ 2/ 5	0	0	2/ 2/ 0/ 0	1	0	19	42.0	1.087
20/16/ 1/ 3	3	0	13/13/ 0/ 0	7	2	42	53.5	1.265
20/16/ 0/ 4	1	0	1/ 1/ 0/ 0	4	0	25	43.5	0.966
26/19/ 2/ 5	0	0	1/ 1/ 0/ 0	1	0	28	44.0	1.104
16/11/ 1/ 4	1	0	1/ 1/ 0/ 0	2	0	19	41.5	1.178
15/11/ 0/ 4	1	1	4/ 4/ 0/ 0	1	1	21	42.0	0.914
15/10/ 2/ 3	0	0	1/ 1/ 0/ 0	2	1	19	42.0	0.963
20/13/ 3/ 4	0	0	4/ 4/ 0/ 0	1	0	25	43.0	1.108
18/12/ 2/ 4	0	0	2/ 2/ 0/ 0	3	0	23	42.5	1.197
12/ 7/ 1/ 4	0	0	3/ 3/ 0/ 0	2	0	17	40.5	1.337
10/ 8/ 0/ 2	0	0	2/ 2/ 0/ 0	3	0	15	42.0	1.131
24/19/ 2/ 3	2	0	2/ 2/ 0/ 0	2	0	28	43.5	1.502
24/13/ 4/ 7	0	0	4/ 4/ 0/ 0	0	0	28	42.0	0.962
15/11/ 1/ 3	1	0	1/ 1/ 0/ 0	4	1	21	44.5	1.040

TABLE 1. VEHICLE LOSSES, TIME AND RANGE OUTPUT FILE

ACTIVE MINEFIELDS AND TIMES TO DEFENSIVE POSTURE

AVENUE 1			AVENUE 2			AVENUE 3			AVENUE 4			RUN TIME
M1	M2		M1	M2		M1	M2		M1	M2		
1	1	46.0	1	1	34.5	1	1	49.5	1	1	41.0	60.5
1	1	0.0	1	0	0.0	0	1	41.0	1	0	0.0	42.5
1	1	0.0	1	1	36.5	1	0	0.0	0	1	0.0	42.5
1	1	0.0	0	1	0.0	0	1	37.0	1	1	0.0	43.5
0	1	0.0	1	1	0.0	0	1	0.0	1	1	0.0	42.5
1	0	0.0	1	1	40.5	0	1	0.0	0	1	0.0	42.0
0	1	0.0	1	1	40.0	1	1	0.0	0	1	0.0	40.5
1	1	40.0	1	1	40.0	1	1	43.0	0	0	0.0	45.5
1	1	0.0	0	0	42.0	1	1	35.5	1	1	0.0	43.0
1	1	0.0	1	1	40.0	0	1	0.0	0	1	0.0	42.5
1	1	43.5	1	1	41.5	1	1	38.5	1	1	42.5	45.0
0	1	0.0	1	1	0.0	0	1	0.0	0	1	0.0	39.0
0	0	0.0	1	1	45.0	1	1	36.5	1	1	47.5	49.0
1	1	0.0	0	1	0.0	0	1	36.5	1	1	0.0	45.5
1	1	0.0	1	0	0.0	0	1	0.0	1	1	0.0	42.5
0	1	0.0	1	1	38.0	1	1	40.0	1	1	0.0	44.0
1	1	0.0	0	1	0.0	1	1	36.0	1	1	0.0	39.5
0	1	0.0	0	1	0.0	1	1	36.5	0	1	0.0	41.0
0	1	0.0	1	1	0.0	0	1	0.0	1	1	0.0	43.0
1	1	0.0	0	1	0.0	1	1	37.0	1	1	0.0	43.0
0	1	0.0	1	1	0.0	0	0	0.0	1	1	0.0	40.5
1	1	0.0	1	1	0.0	0	1	0.0	1	0	0.0	44.0
1	1	0.0	1	1	0.0	1	1	36.5	0	1	0.0	41.0
1	0	40.5	1	1	33.5	0	0	38.5	1	1	0.0	41.0
1	1	0.0	1	1	0.0	0	1	38.0	0	1	0.0	41.5
1	1	0.0	1	1	0.0	0	1	37.0	1	0	0.0	43.0
1	1	0.0	0	1	0.0	0	1	0.0	1	1	0.0	40.5
1	1	41.5	1	0	37.5	1	0	38.5	1	1	46.0	49.0
1	1	0.0	0	0	0.0	1	1	45.0	1	1	0.0	46.0
1	1	0.0	0	1	0.0	1	1	0.0	0	0	0.0	40.5
1	1	0.0	1	1	0.0	0	1	0.0	0	1	0.0	43.5
1	1	0.0	0	1	0.0	1	1	0.0	0	1	0.0	35.5
0	1	0.0	1	1	36.0	1	1	36.5	0	1	0.0	40.5
1	1	0.0	0	1	0.0	1	1	0.0	1	1	0.0	41.5
1	1	0.0	1	1	36.5	1	1	37.5	0	1	0.0	46.5
1	1	0.0	0	1	0.0	0	0	40.0	0	1	0.0	43.5
1	1	0.0	1	1	0.0	1	1	38.0	0	1	0.0	45.5
1	1	0.0	1	1	0.0	0	1	38.5	0	1	0.0	42.0
1	0	0.0	1	1	0.0	1	0	38.0	0	1	0.0	42.5
1	1	0.0	0	0	0.0	0	1	0.0	1	0	0.0	38.0
0	1	0.0	1	1	0.0	0	1	40.5	0	1	0.0	46.0
1	0	39.0	1	1	39.0	1	1	35.5	1	1	0.0	41.5
1	1	0.0	0	1	45.5	1	1	33.0	0	1	44.5	46.0
1	1	0.0	0	0	0.0	1	1	36.5	1	1	0.0	42.0
1	1	0.0	0	1	0.0	1	1	35.5	0	0	0.0	42.0
1	1	41.5	1	1	43.0	1	1	38.0	1	1	0.0	44.5
1	1	38.0	0	1	41.5	0	1	40.5	0	1	0.0	42.0
1	0	0.0	1	1	40.5	1	1	35.5	1	1	0.0	43.5
1	1	0.0	0	1	0.0	1	1	0.0	0	1	0.0	37.5
1	0	0.0	1	1	0.0	0	1	0.0	1	1	0.0	43.5

TABLE 2. MINEFIELD STATUS AND DEFENSIVE POSTURE TIME OUTPUT FILE

No Minefields/Direct Fire

Unit Configuration

Measure of Effectiveness	14/0/0	12/1/1	10/2/2	8/3/3	10/3/1
1	0.239 (0.098)	0.251 (0.100)	0.252 (0.099)	0.268 (0.105)	0.235 (0.092)
2	N/A	N/A	N/A	N/A	N/A
3	0.239 (0.098)	0.251 (0.098)	0.252 (0.099)	0.268 (0.105)	0.235 (0.092)
4	N/A	N/A	N/A	N/A	N/A
5	N/A	7.020 (2.808)	3.525 (1.384)	2.500 (0.983)	3.295 (1.291)
6	N/A	7.020 (2.808)	3.525 (1.384)	2.500 (0.983)	3.295 (1.291)
7	16/200	21/200	14/200	20/200	13/200
8	0 0 0 16	0 0 0 21	0 0 0 14	0 0 0 20	0 0 0 13
9	24.21 (0.969)	36.80 (1.484)	36.85 (1.543)	36.92 (1.592)	36.28 (1.614)
10	0.773 (0.227)	1.047 (0.242)	1.045 (0.271)	1.050 (0.267)	1.127 (0.294)
11	0.548 (0.204)	0.378 (0.139)	0.379 (0.136)	0.402 (0.144)	0.359 (0.128)

TABLE 3. NO MINEFIELDS/DIRECT FIRE STATISTICS

Prob Minefields/Direct Fire

Unit Configuration

Measure of Effectiveness

	14/0/0	12/1/1	10/2/2	8/3/3	10/3/1
1	0.338 (0.127)	0.292 (0.105)	0.328 (0.147)	0.317 (0.133)	0.308 (0.430)
2	0.105 (0.064)	0.153 (0.076)	0.170 (0.087)	0.160 (0.084)	0.174 (0.085)
3	0.444 (0.152)	0.446 (0.144)	0.498 (0.181)	0.477 (0.173)	0.482 (0.184)
4	N/A	4.300 (2.126)	2.380 (1.220)	1.493 (0.782)	2.435 (1.195)
5	N/A	8.190 (2.948)	4.590 (2.056)	2.963 (1.246)	4.320 (1.997)
6	N/A	12.49 (4.039)	6.970 (2.538)	4.457 (1.613)	6.755 (2.570)
7	74/200	71/200	77/200	85/200	81/200
8	1 4 27 42	0 0 10 61	0 4 12 61	0 0 11 84	0 12 4 65
9	33.87 (11.37)	40.02 (5.372)	41.63 (9.287)	40.45 (5.358)	42.70 (13.29)
10	2.096 (3.742)	1.098 (0.300)	1.015 (0.335)	1.026 (0.305)	1.062 (0.292)
11	0.737 (0.160)	0.615 (0.153)	0.660 (0.148)	0.648 (0.184)	0.629 (0.151)

TABLE 4. PROBABILITY OF MINEFIELDS/DIRECT FIRE STATISTICS

100% Minefields/Direct Fire

Unit Configuration

Measure of Effectiveness	14/0/0	12/1/1	10/2/2	8/3/3	10/3/1
1	0.401 (0.150)	0.357 (0.150)	0.385 (0.124)	0.381 (0.169)	0.361 (0.142)
2	0.187 (0.070)	0.258 (0.078)	0.253 (0.053)	0.236 (0.056)	0.265 (0.064)
3	0.589 (0.170)	0.615 (0.172)	0.639 (0.135)	0.616 (0.185)	0.626 (0.157)
4	N/A	7.230 (2.174)	3.550 (0.739)	2.203 (0.526)	3.705 (0.896)
5	N/A	9.990 (4.198)	5.395 (1.736)	3.553 (1.579)	5.060 (1.989)
6	N/A	17.22 (4.319)	8.945 (2.056)	5.757 (1.730)	8.765 (2.193)
7	124/200	131/200	145/200	142/200	152/200
8	2 21 50 50	0 11 24 96	0 14 12 119	0 10 24 108	0 8 28 116
9	46.14 (14.68)	46.90 (12.52)	47.00 (13.34)	46.27 (12.49)	46.18 (11.42)
10	1.617 (0.445)	1.314 (0.305)	1.045 (0.369)	1.022 (0.373)	1.030 (0.378)
11	0.729 (0.161)	0.740 (0.114)	0.771 (0.102)	0.744 (0.137)	0.762 (0.113)

TABLE 5. 100% MINEFIELDS/DIRECT FIRE STATISTICS

100% Minefields/No Direct Fire

Unit Configuration

Measure of Effectiveness	14/0/0	12/1/1	10/2/2	8/3/3	10/3/1
1	N/A	N/A	N/A	N/A	N/A
2	0.213 (0.052)	0.346 (0.093)	0.356 (0.080)	0.321 (0.062)	0.368 (0.080)
3	0.213 (0.052)	0.346 (0.093)	0.356 (0.080)	0.321 (0.062)	0.368 (0.080)
4	N/A	9.700 (2.619)	4.990 (1.116)	2.997 (0.578)	5.155 (1.126)
5	N/A	N/A	N/A	N/A	N/A
6	N/A	9.700 (2.619)	4.990 (1.116)	2.997 (0.578)	5.155 (1.126)
7	2/200	44/200	35/200	14/200	35/200
8	0 2 0 0	0 0 15 29	0 0 0 35	0 0 0 14	0 0 0 35
9	62.83 (4.738)	49.91 (7.878)	44.15 (1.408)	44.08 (0.798)	43.92 (1.153)
10	0.218 (0.022)	0.217 (0.027)	0.215 (0.028)	0.214 (0.024)	0.214 (0.022)
11	0.192 (0.056)	0.396 (0.119)	0.452 (0.102)	0.409 (0.083)	0.470 (0.105)

TABLE 6. 100% MINEFIELDS NO DIRECT FIRE STATISTICS

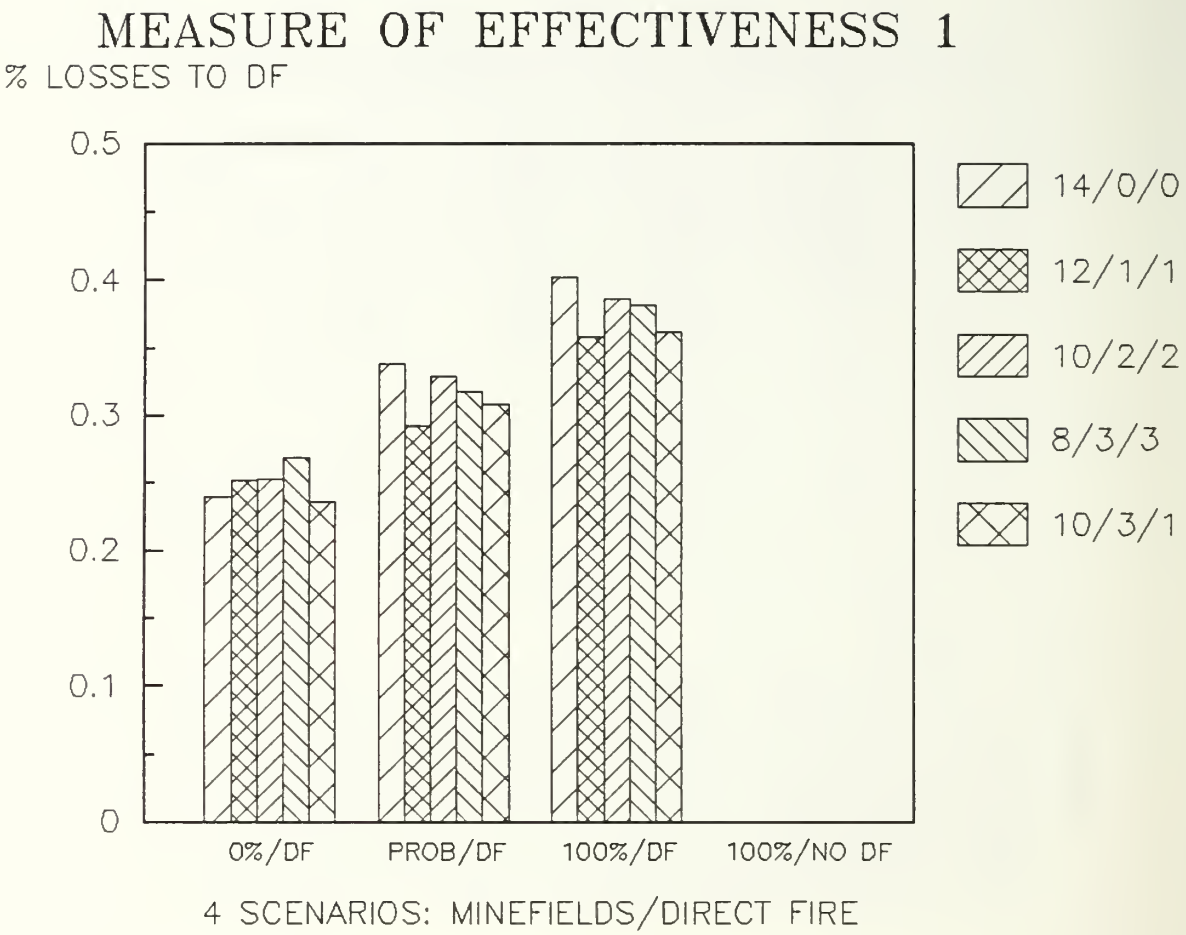


Figure 12. Model 1 Measure of Effectivess 1

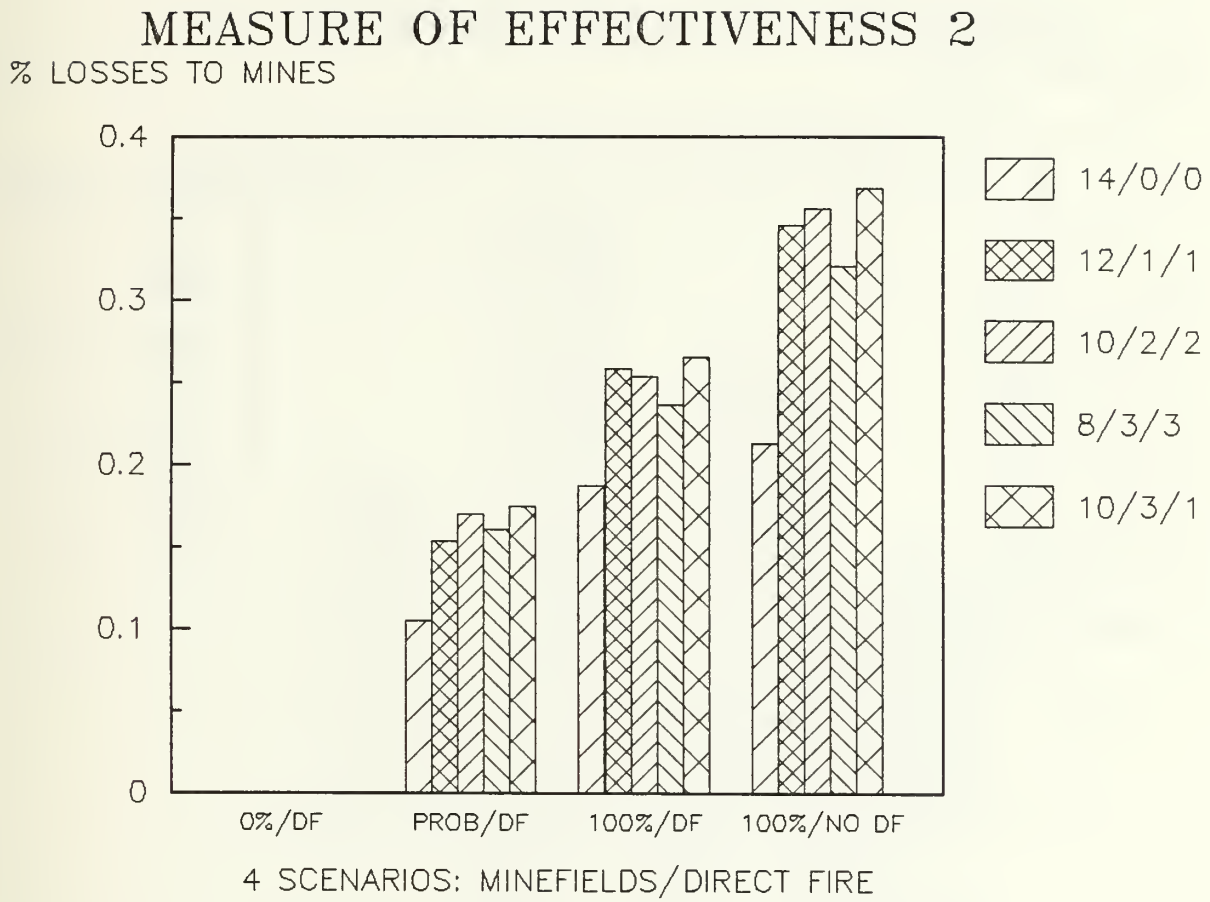


Figure 13. Model 1 Measure of Effectiveness 2

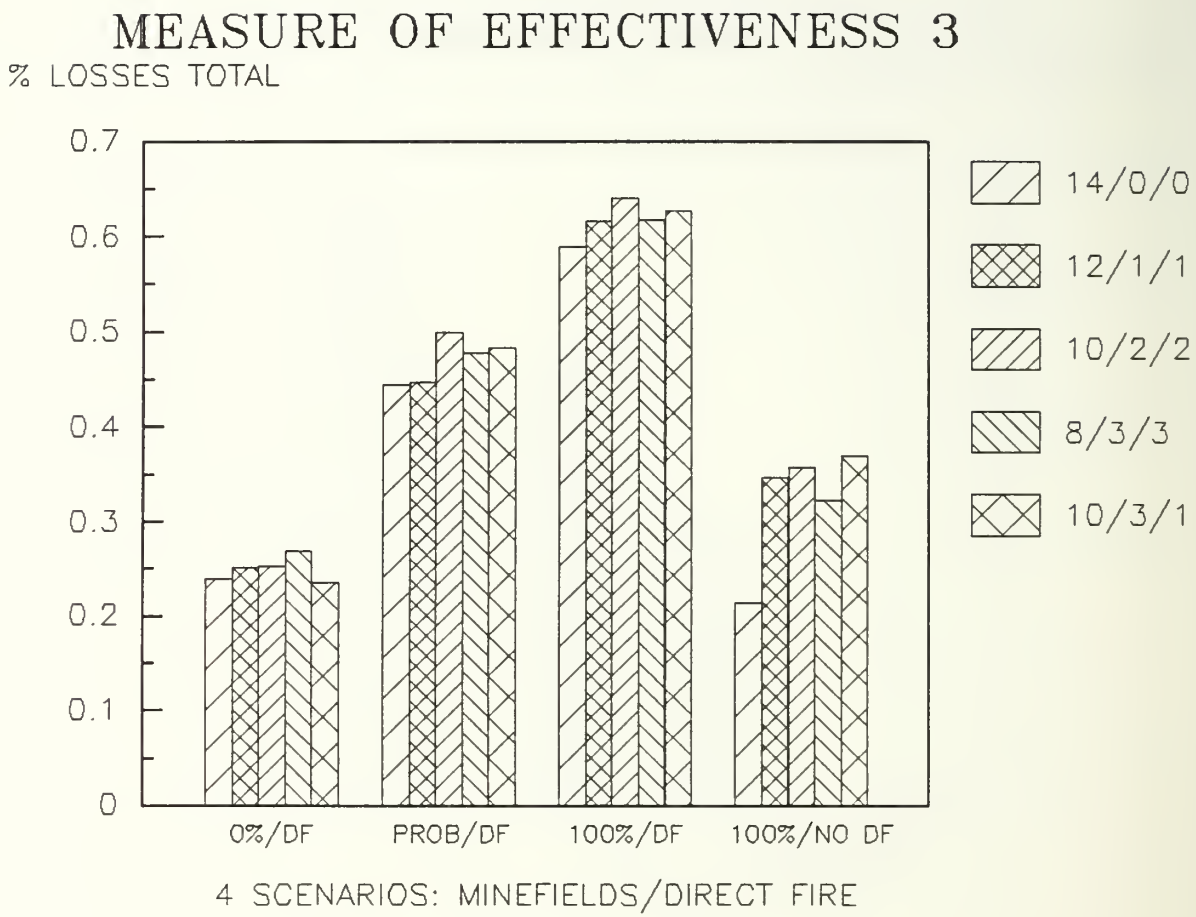


Figure 14. Model 1 Measure of Effectiveness 3

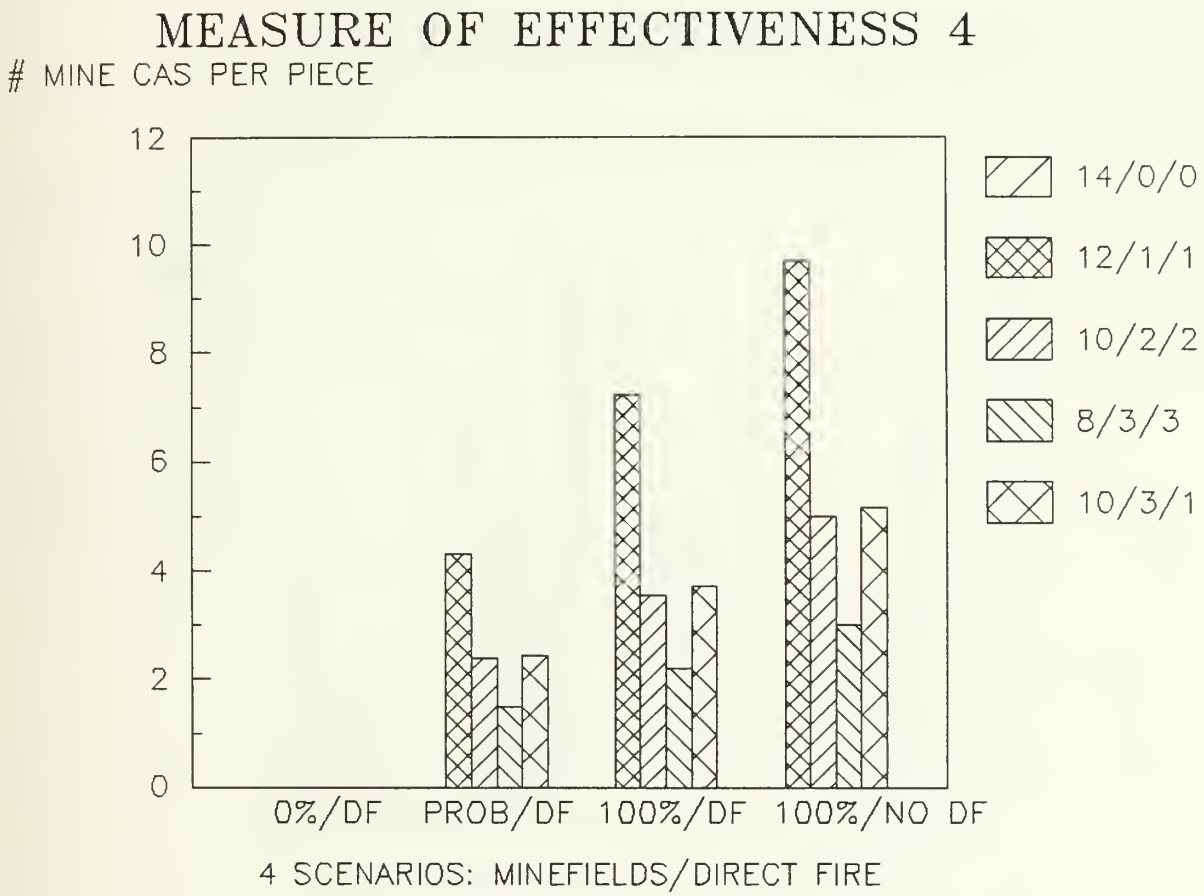


Figure 15. Model 1 Measure of Effectiveness 4

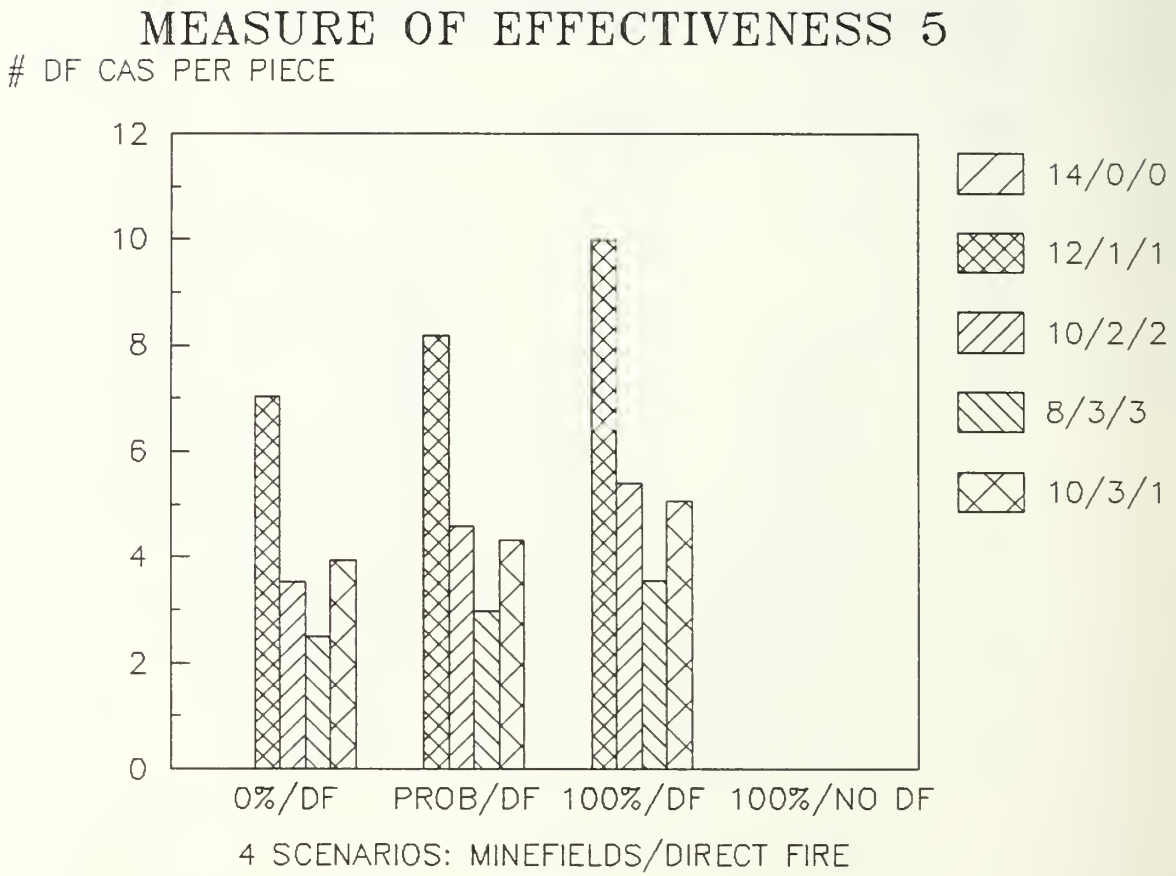


Figure 16. Model 1 Measure of Effectiveness 5

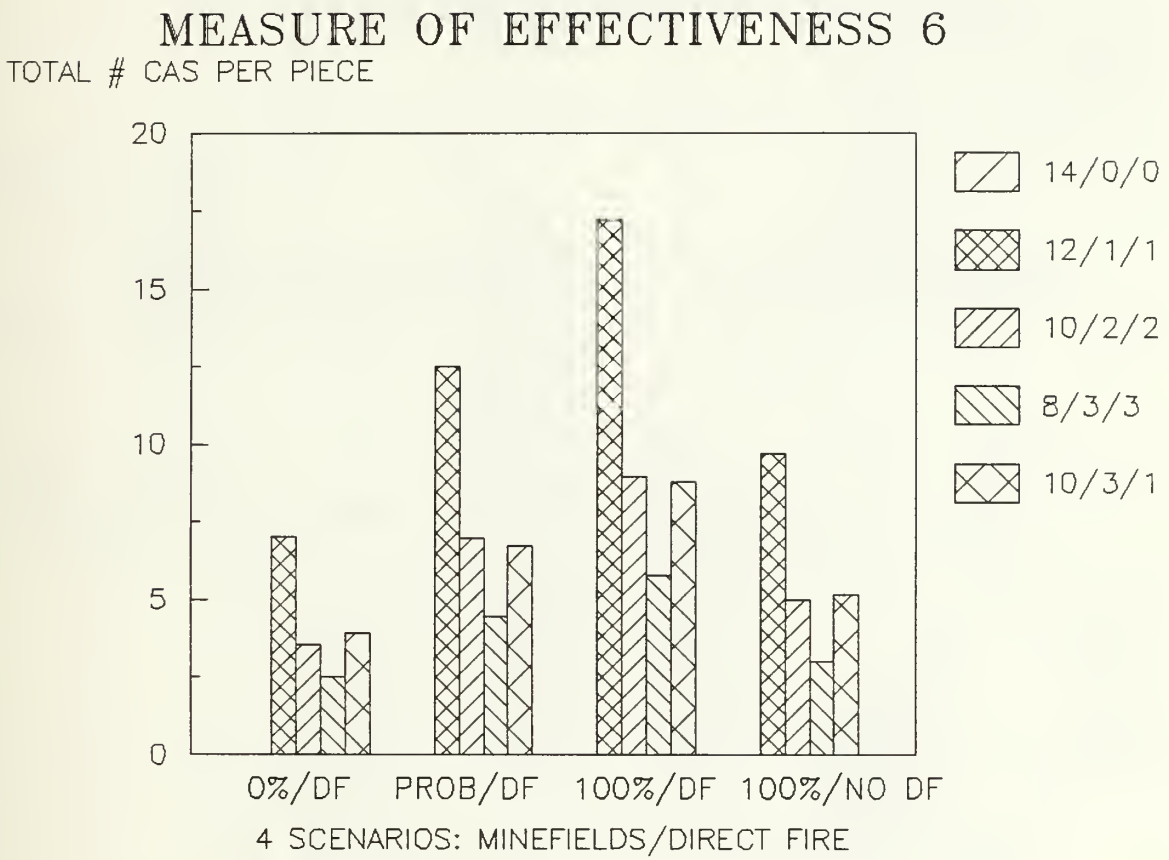


Figure 17. Model 1 Measure of Effectiveness 6

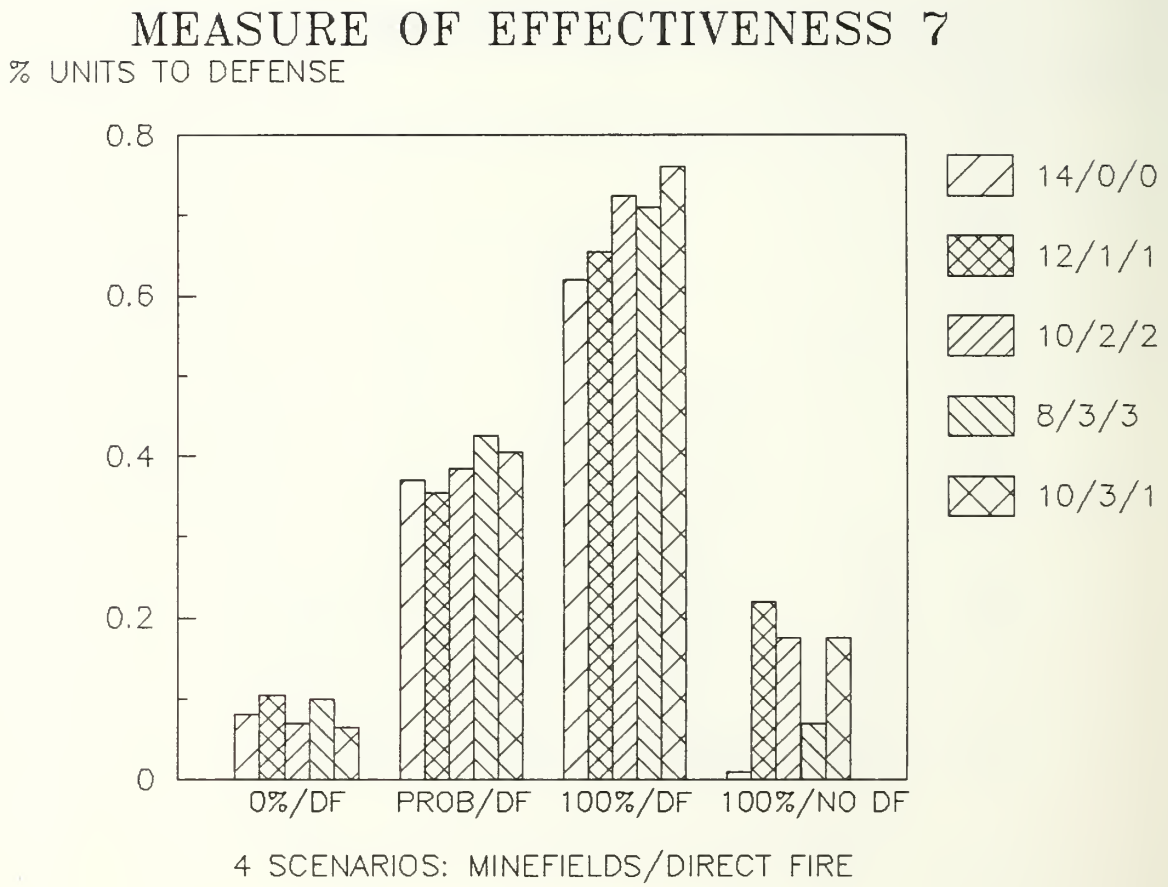


Figure 18. Measure of Effectiveness 7

MEASURE OF EFFECTIVENESS 8

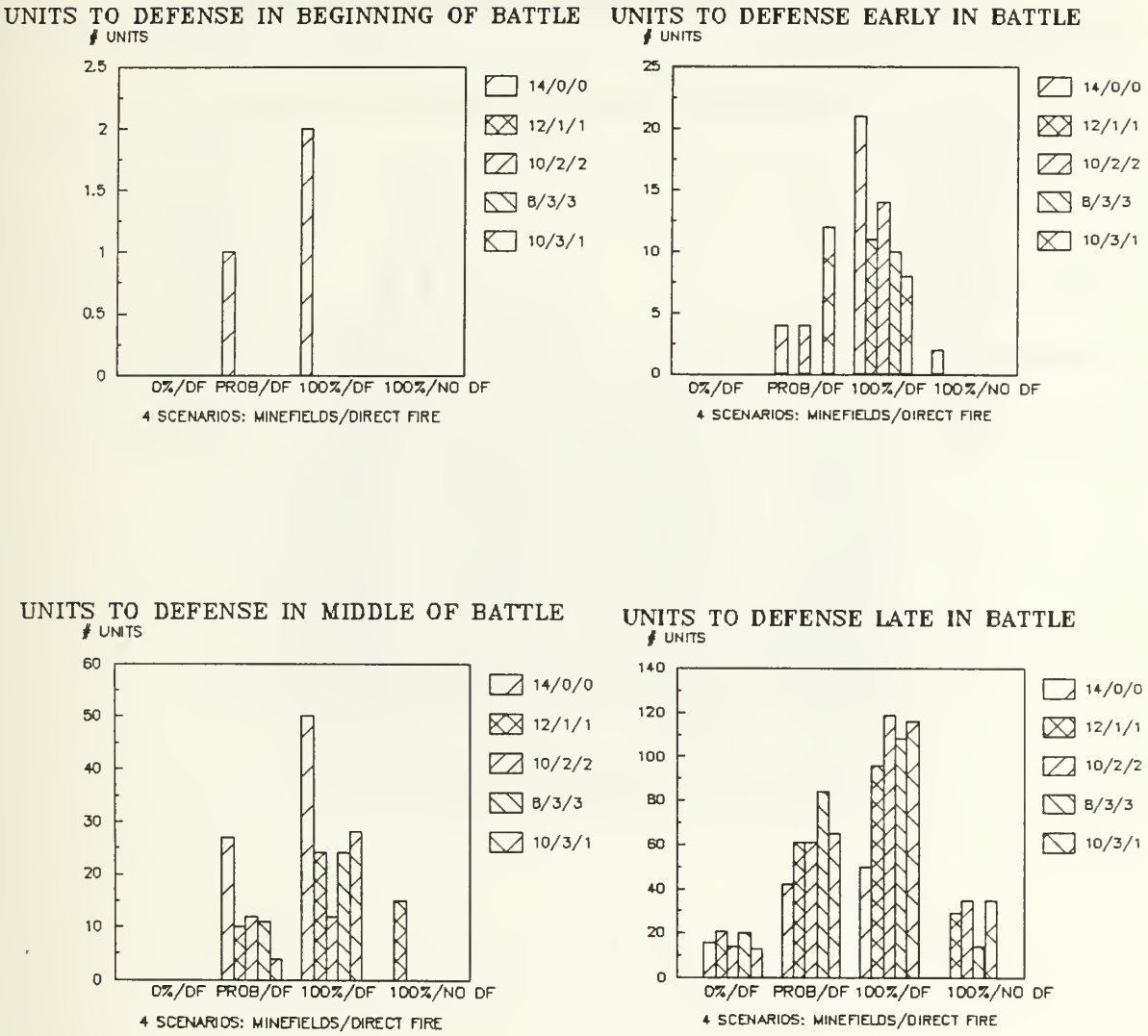


Figure 19. Model 1 Measure of Effectiveness 8

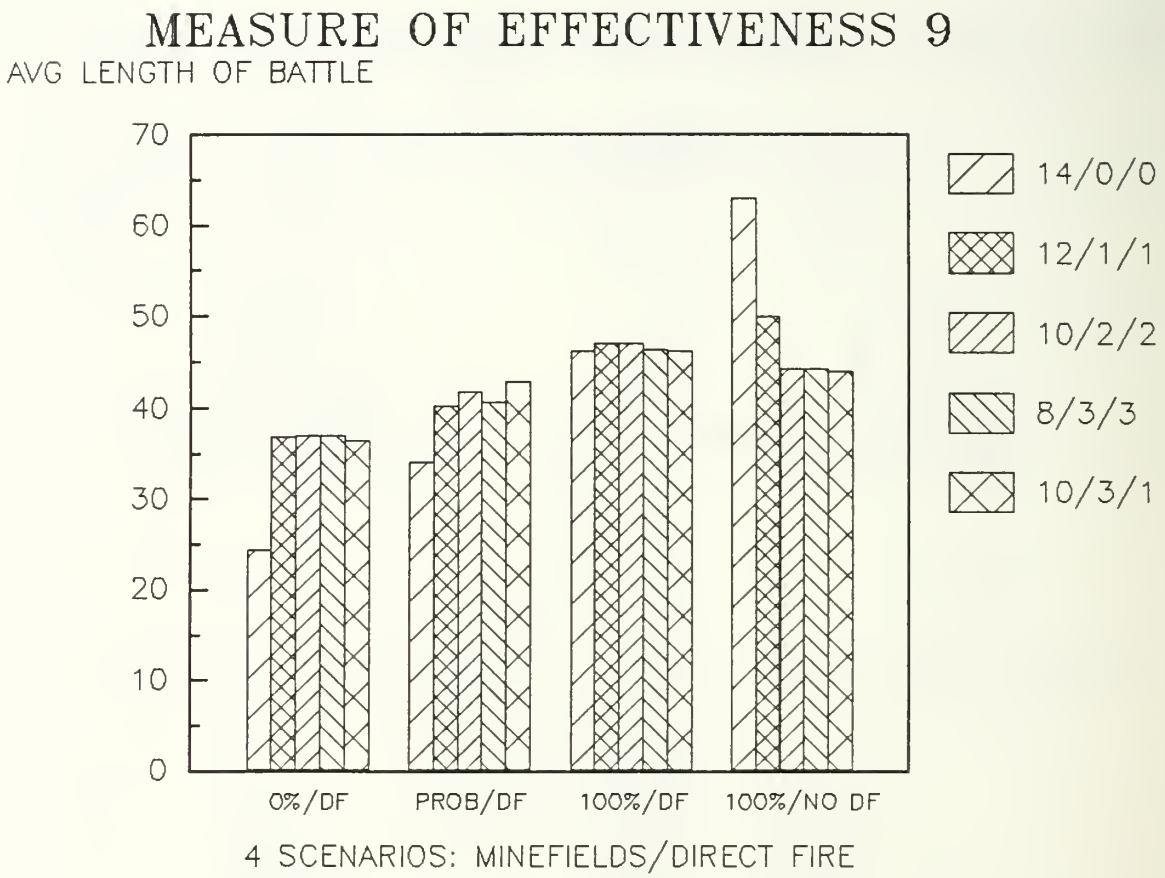


Figure 20. Model 1 Measure of Effectiveness 9

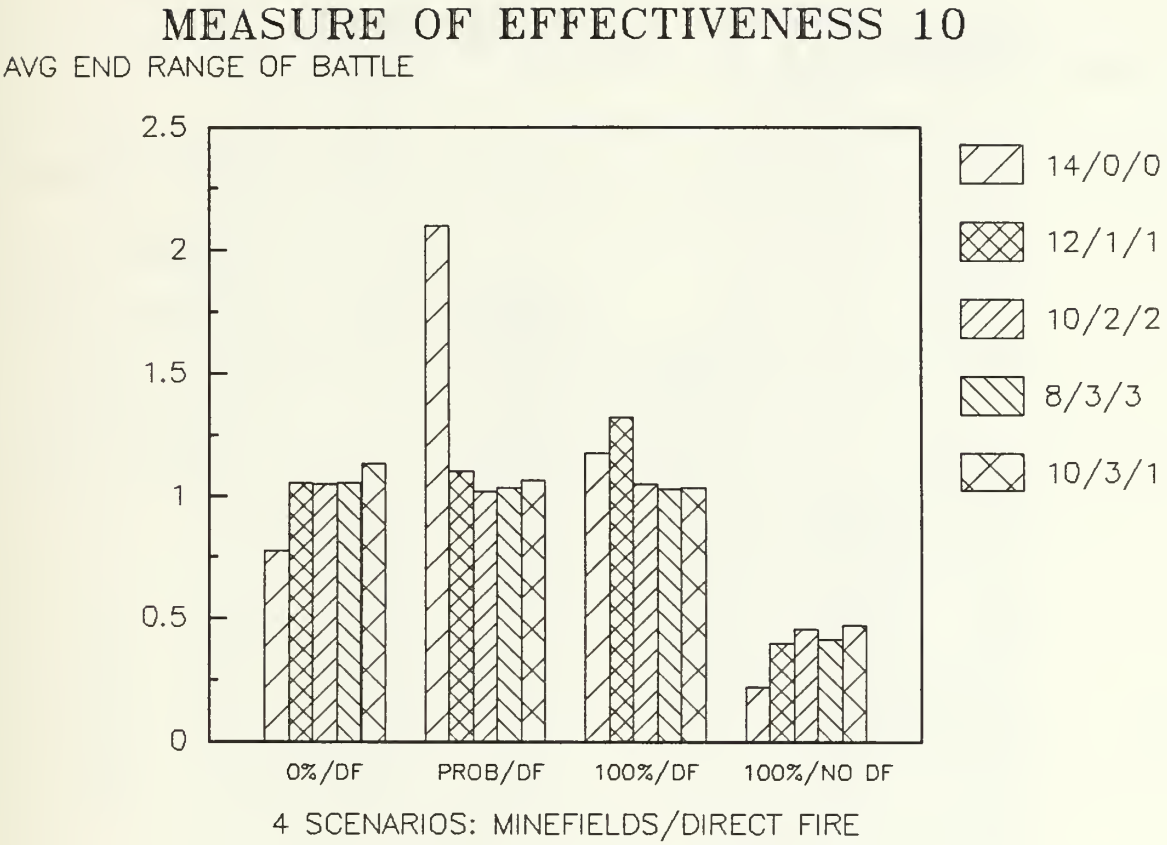


Figure 21. Model 1 Measure of Effectiveness 10

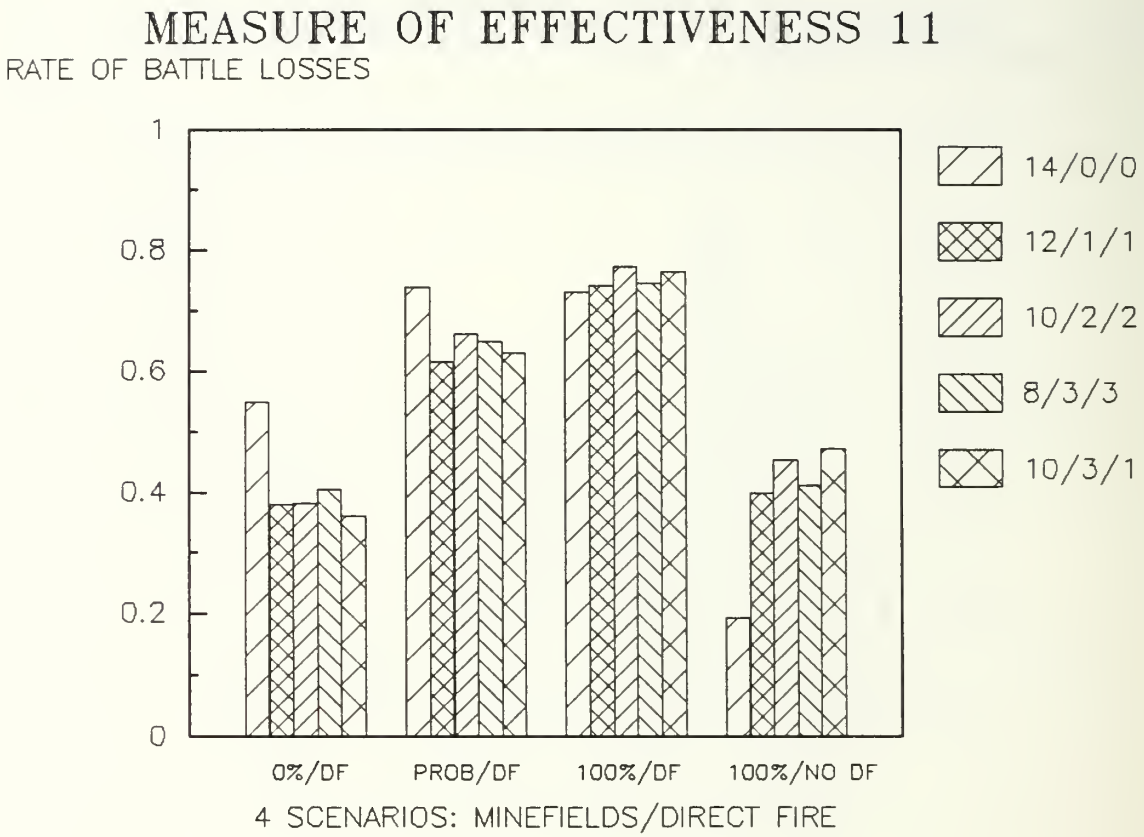


Figure 22. Model 1 Measure of Effectiveness 11

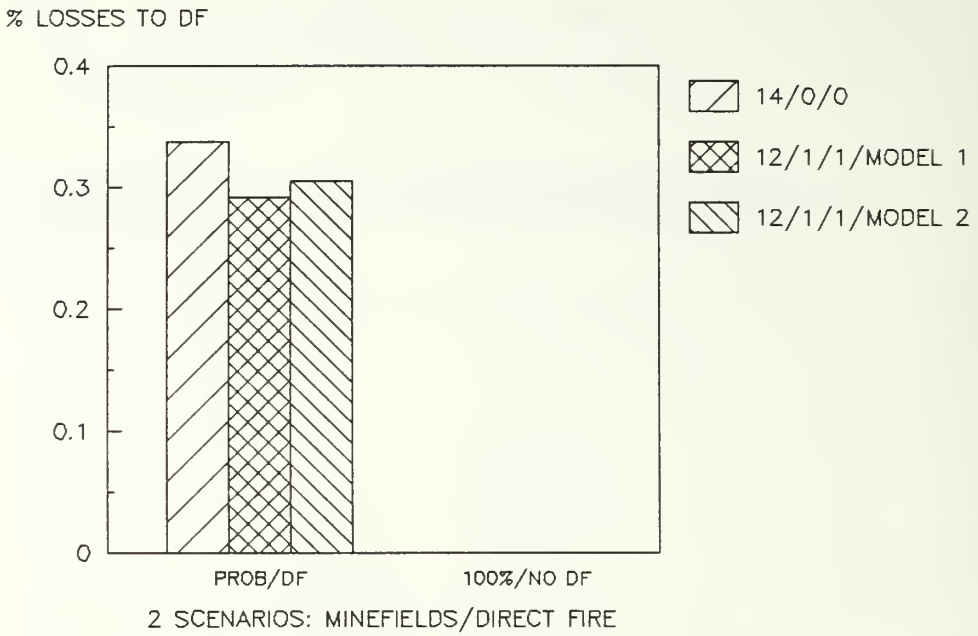
MODEL 2 STATISTICS

Unit Configuration

Measure of Effectiveness	12/1/1 PROB/DF	12/1/1 100%/ NO DF		10/2/2 PROB/DF	10/2/2 100%/ NO DF
1	0.305 (0.112)	N/A		0.343 (0.114)	N/A
2	0.098 (0.054)	0.241 (0.102)		0.125 (0.086)	0.257 (0.973)
3	0.403 (0.134)	0.241 (0.102)		0.469 (0.162)	0.257 (0.973)
4	2.760 (1.532)	6.750 (2.856)		1.755 (1.207)	3.600 (1.363)
5	8.540 (3.134)	N/A		4.810 (1.601)	N/A
6	11.30 (3.751)	6.750 (2.856)		6.565 (2.267)	3.600 (1.363)
7	64/200	35/200		91/200	32/200
8	0 0 4 60	0 0 20 15		0 0 6 85	0 0 0 32
9	43.02 (3.620)	55.18 (7.512)		43.71 (3.805)	48.44 (2.251)
10	1.084 (0.438)	0.223 (0.022)		1.122 (0.297)	0.219 (0.027)
11	0.518 (0.144)	0.245 (0.101)		0.590 (0.161)	0.298 (0.112)

TABLE 7 MODEL 2 STATISTICS

MEASURE OF EFFECTIVENESS 1
MODEL 1 VERSUS MODEL 2



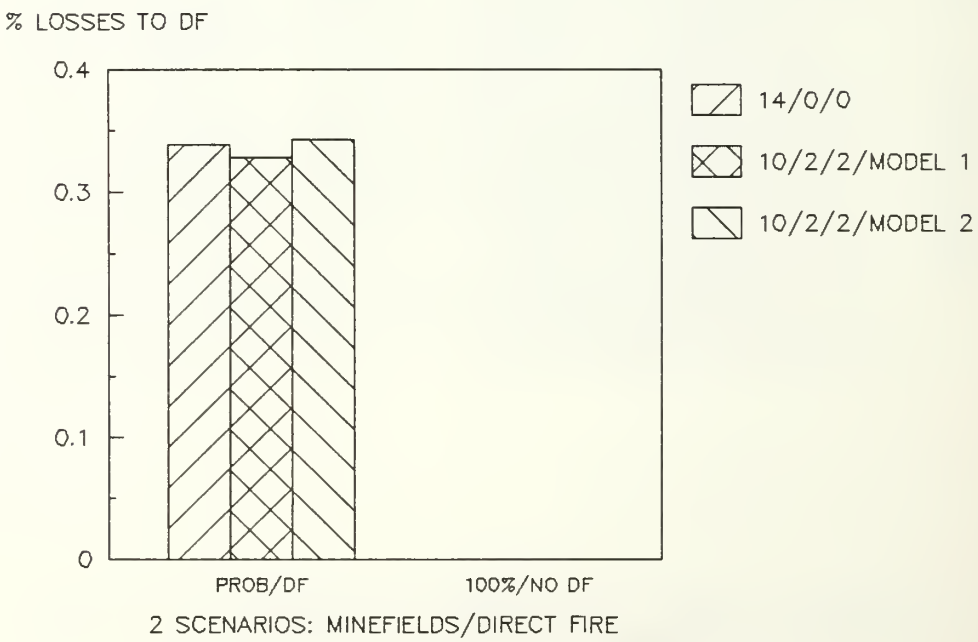
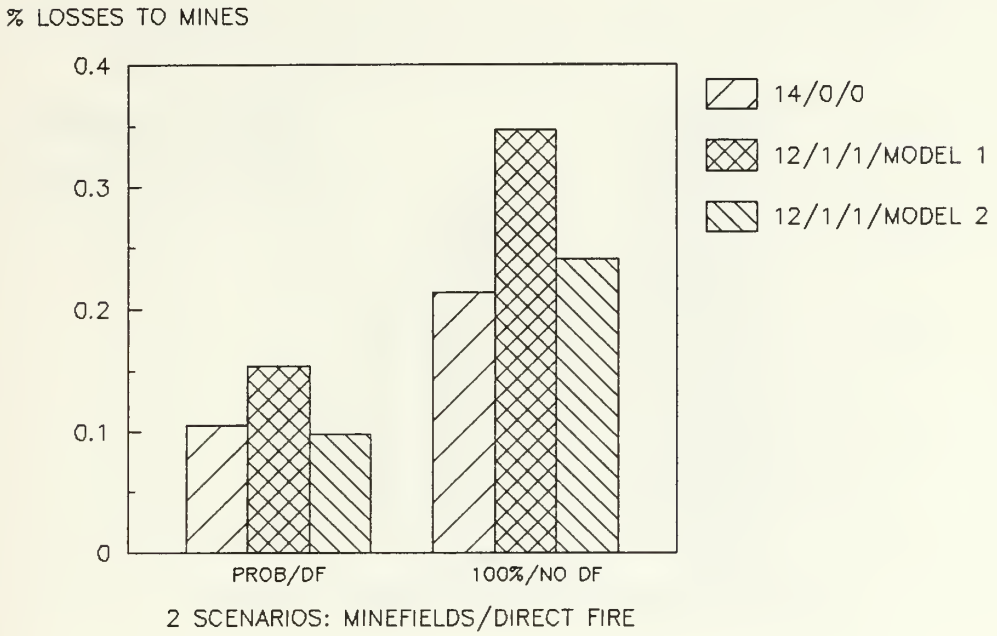


Figure 23. Model 1 versus Model 2
Measure of Effectiveness 1

MEASURE OF EFFECTIVENESS 2
MODEL 1 VERSUS MODEL 2



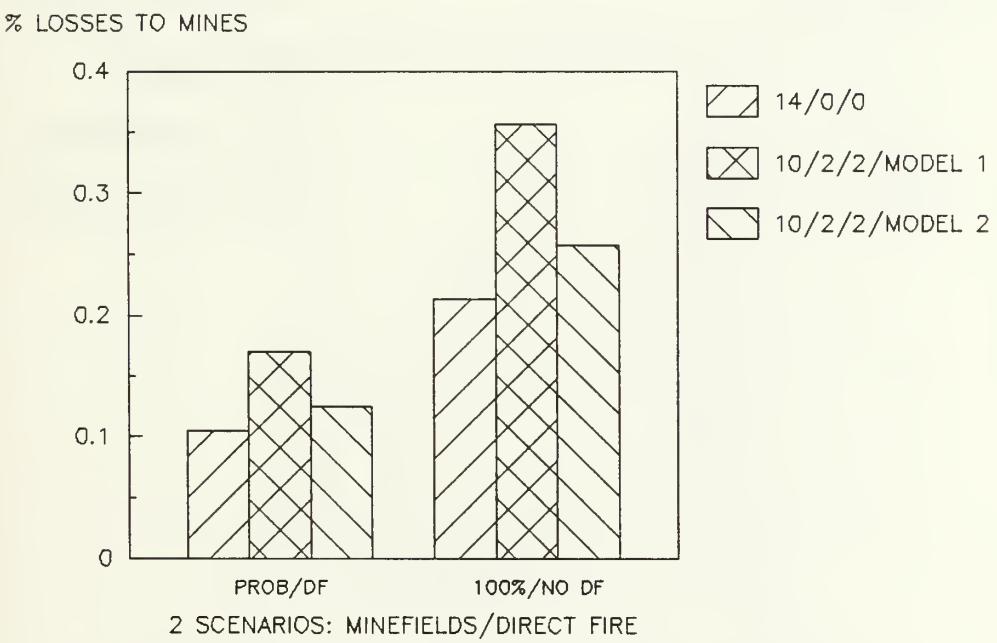


Figure 24. Model 1 versus Model 2
Measure of Effectiveness 2

MEASURE OF EFFECTIVENESS 3
MODEL 1 VERSUS MODEL 2

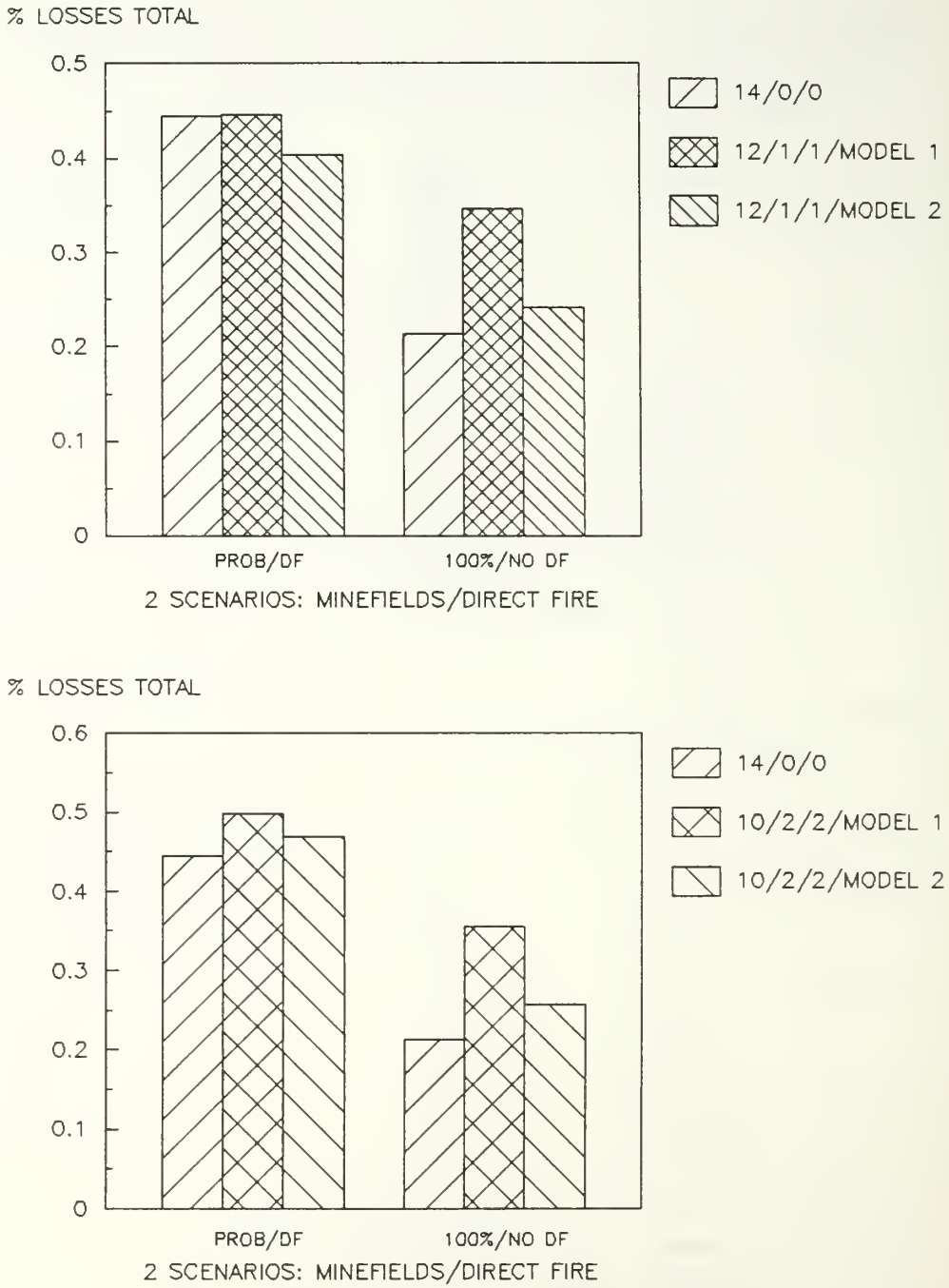
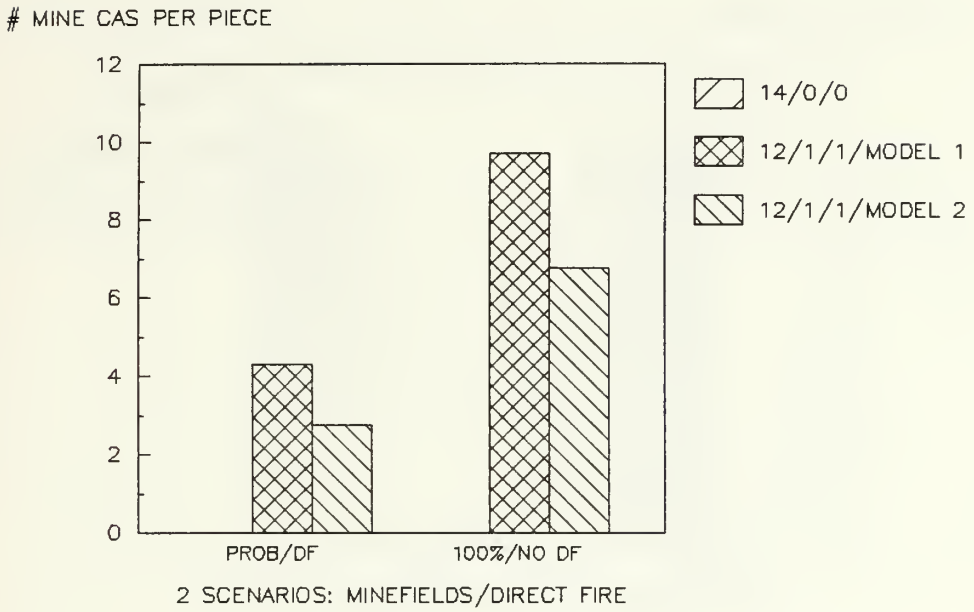


Figure 25. Model 1 versus Model 2
Measure of Effectiveness 3

MEASURE OF EFFECTIVENESS 4
MODEL 1 VERSUS MODEL 2



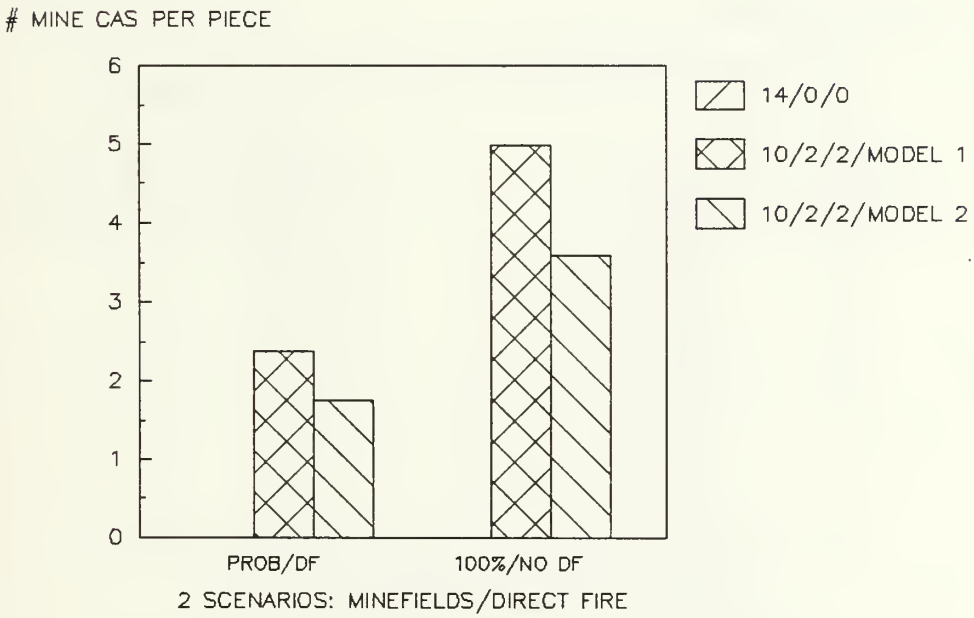
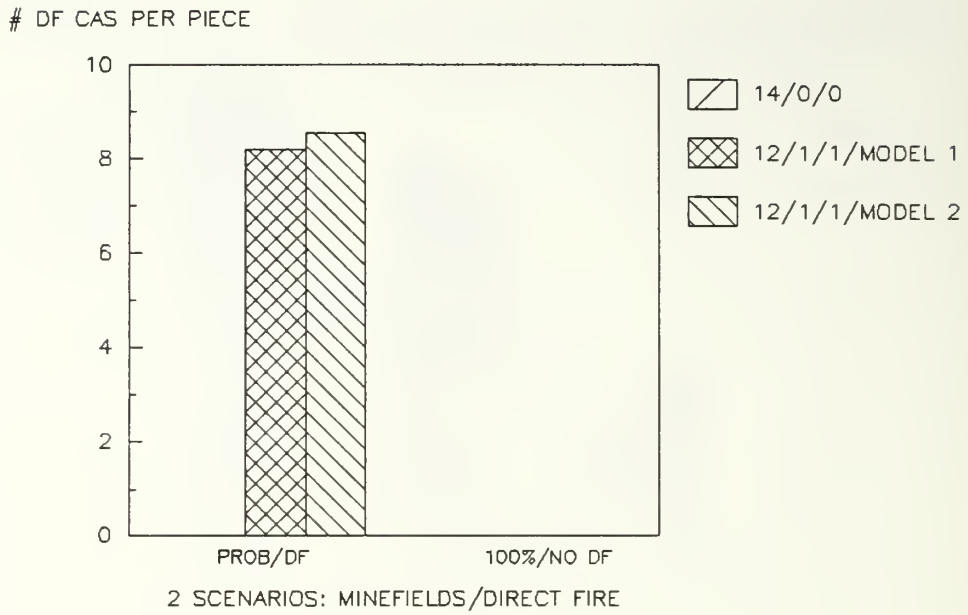


Figure 26. Model 1 versus Model 2
Measure of Effectiveness 4

MEASURE OF EFFECTIVENESS 5
MODEL 1 VERSUS MODEL 2



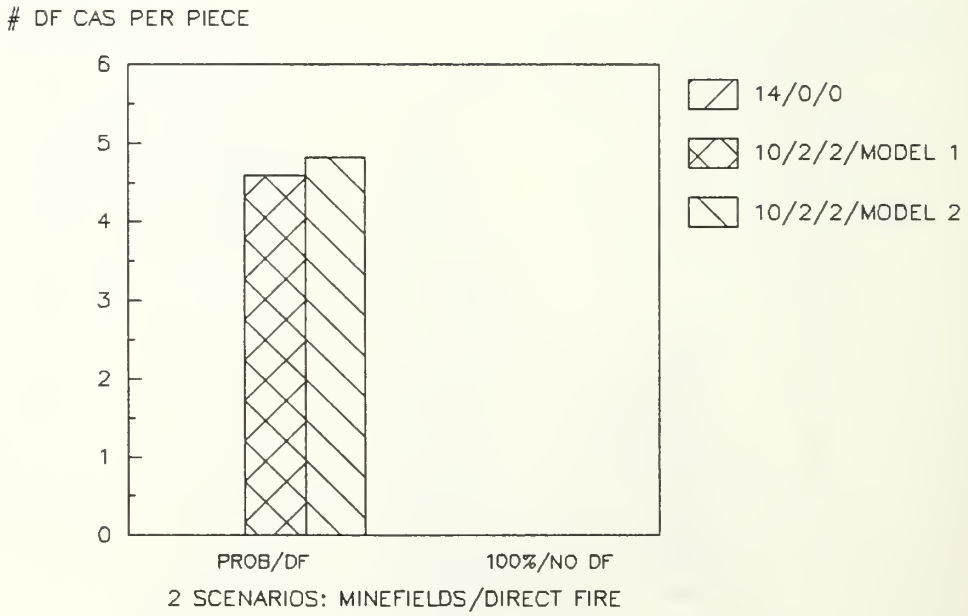
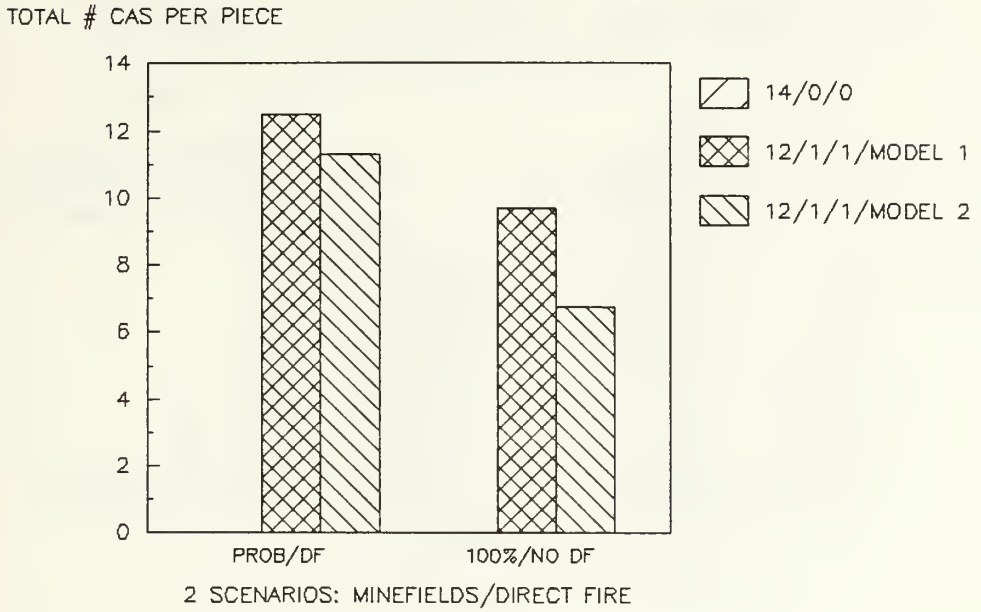


Figure 27. Model 1 versus Model 2
Measure of Effectiveness 5

MEASURE OF EFFECTIVENESS 6
MODEL 1 VERSUS MODEL 2



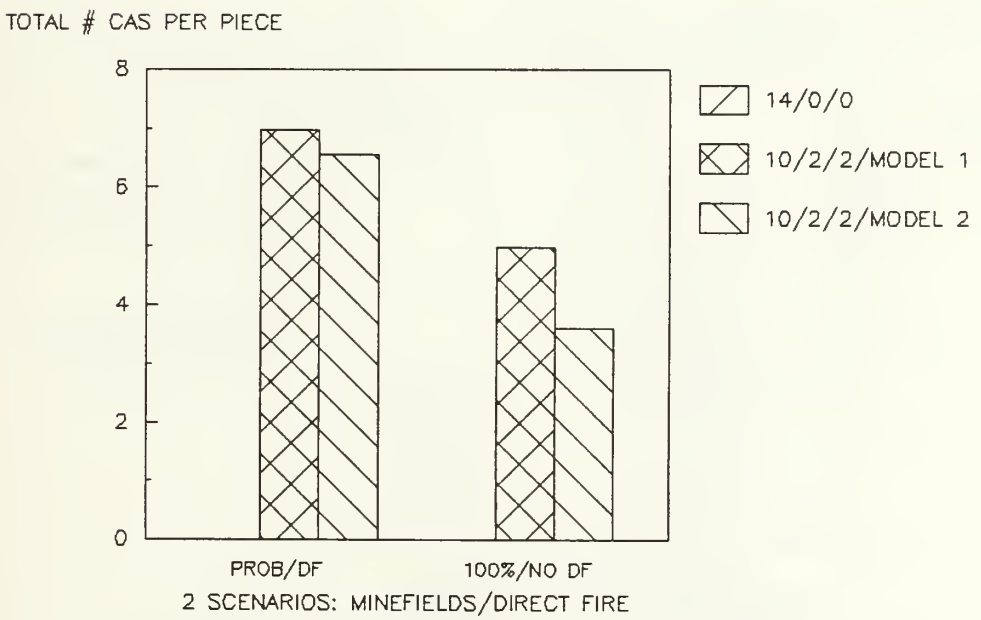
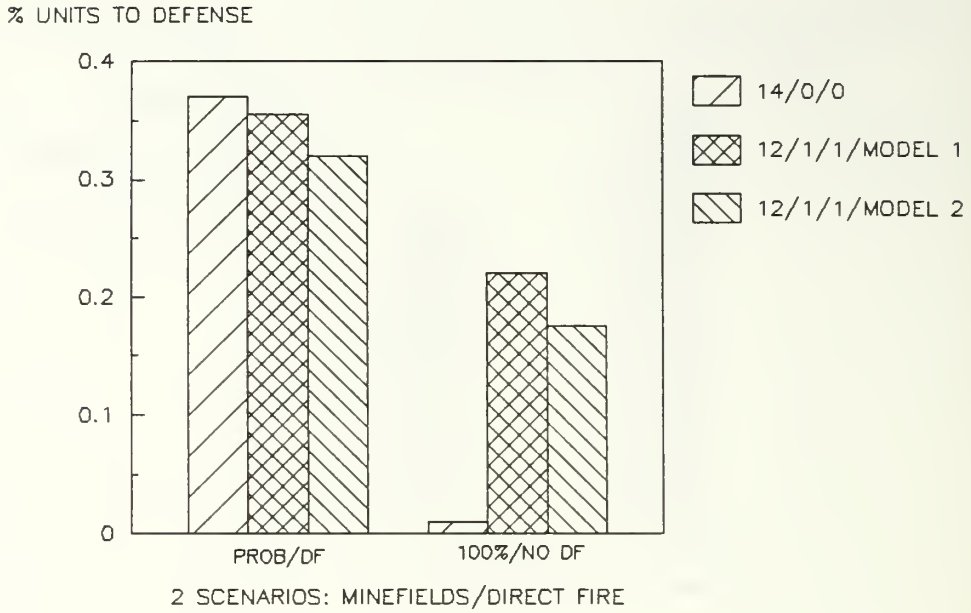


Figure 28. Model 1 versus Model 2
Measure of Effectiveness 6

MEASURE OF EFFECTIVENESS 7
MODEL 1 VERSUS MODEL 2



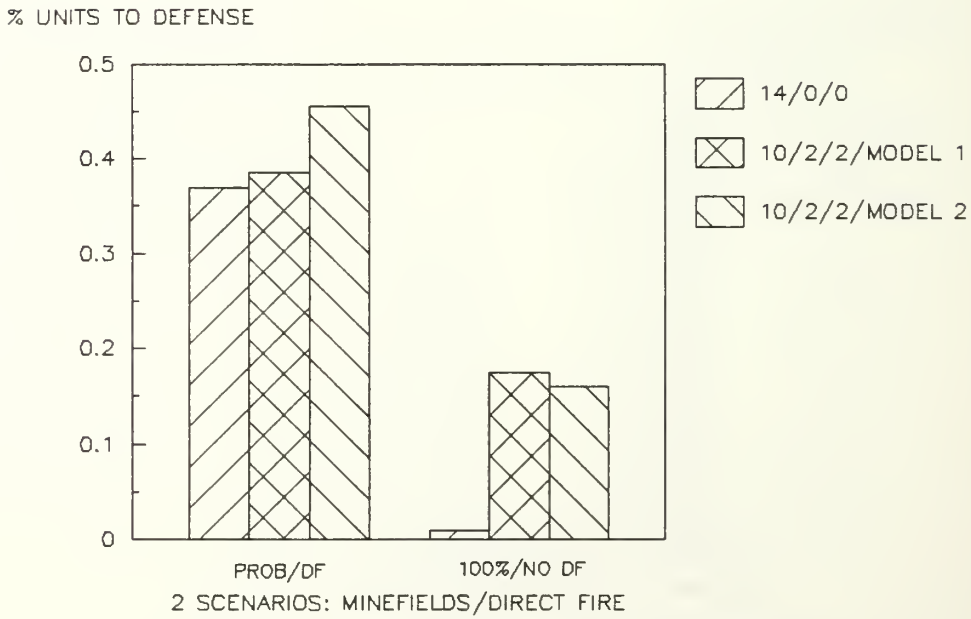
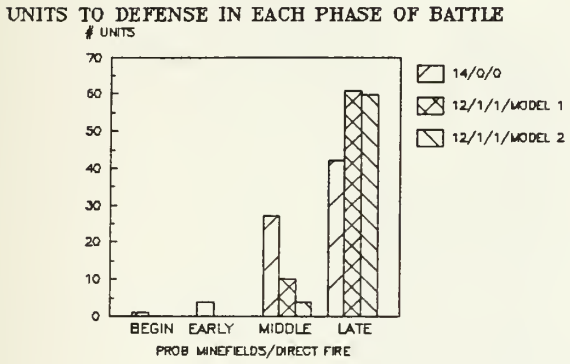
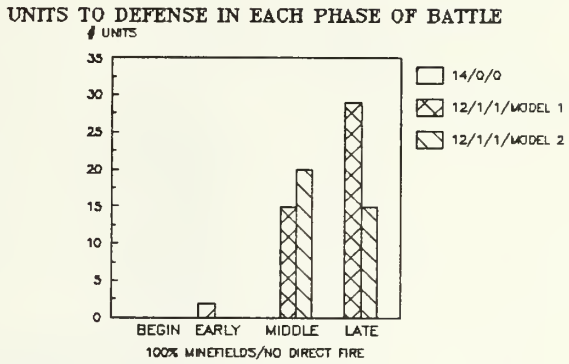
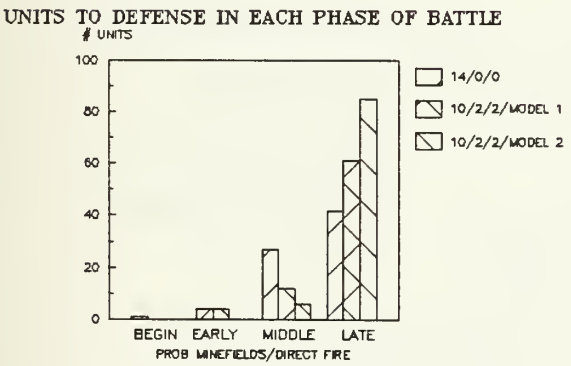


Figure 29. Model 1 versus Model 2
Measure of Effectiveness 7

MEASURE OF EFFECTIVENESS 8
MODEL 1 VERSUS MODEL 2







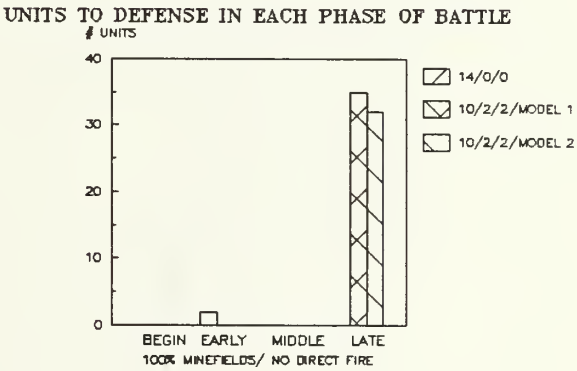
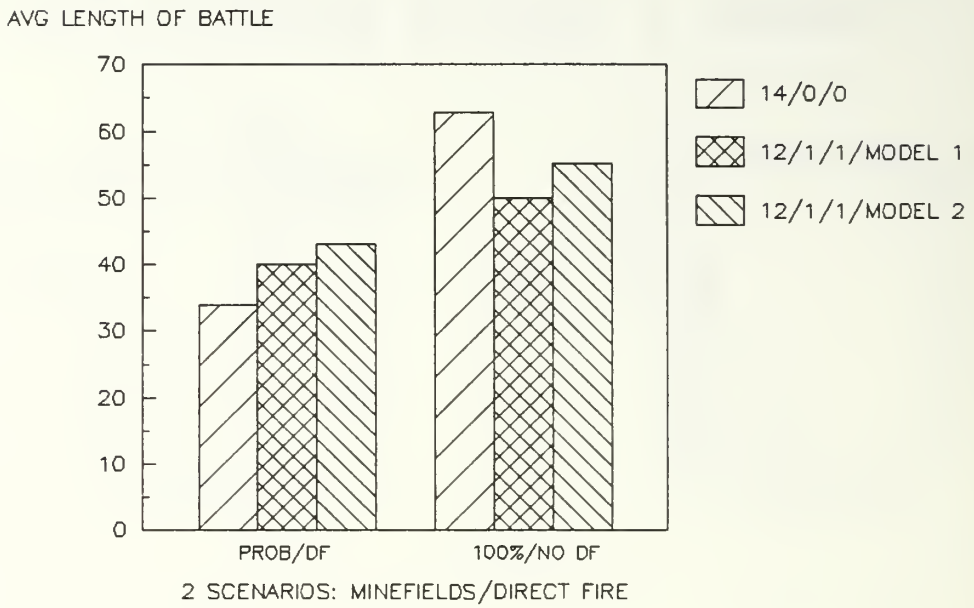


Figure 30. Model 1 versus Model 2
Measure of Effectiveness 8

MEASURE OF EFFECTIVENESS 9
MODEL 1 VERSUS MODEL 2



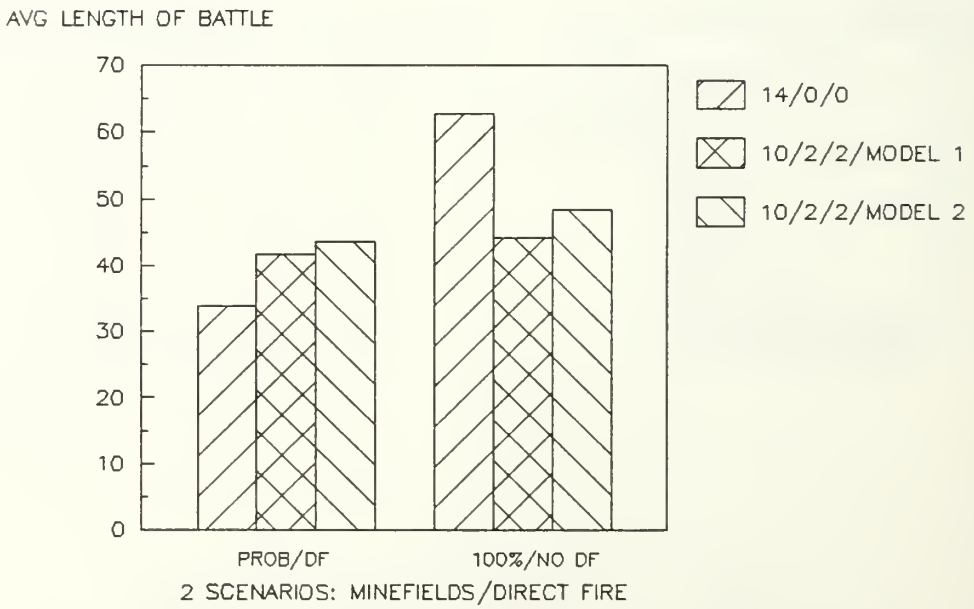
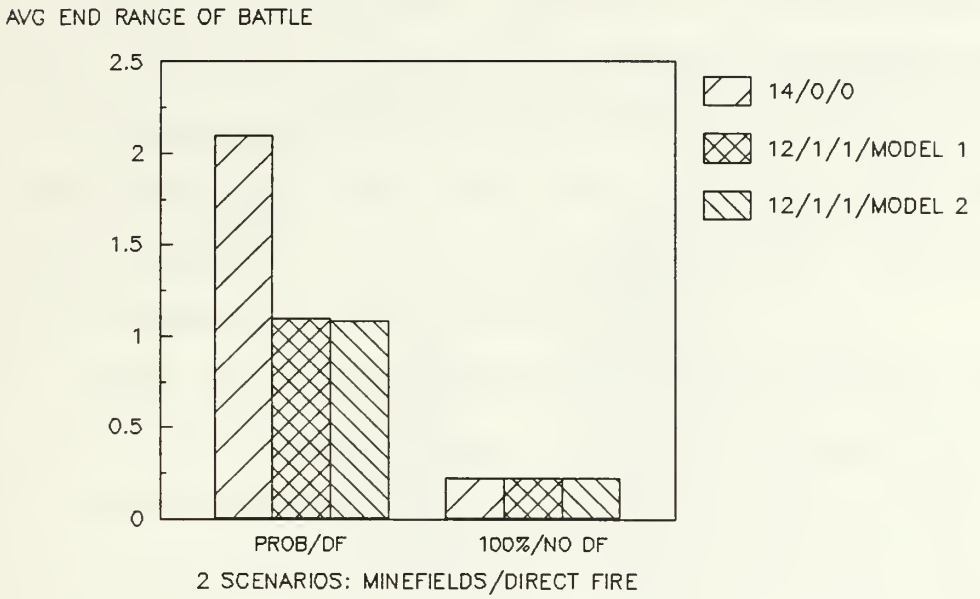


Figure 31. Model 1 versus Model 2
Measure of Effectiveness 9

MEASURE OF EFFECTIVENESS 10
MODEL 1 VERSUS MODEL 2



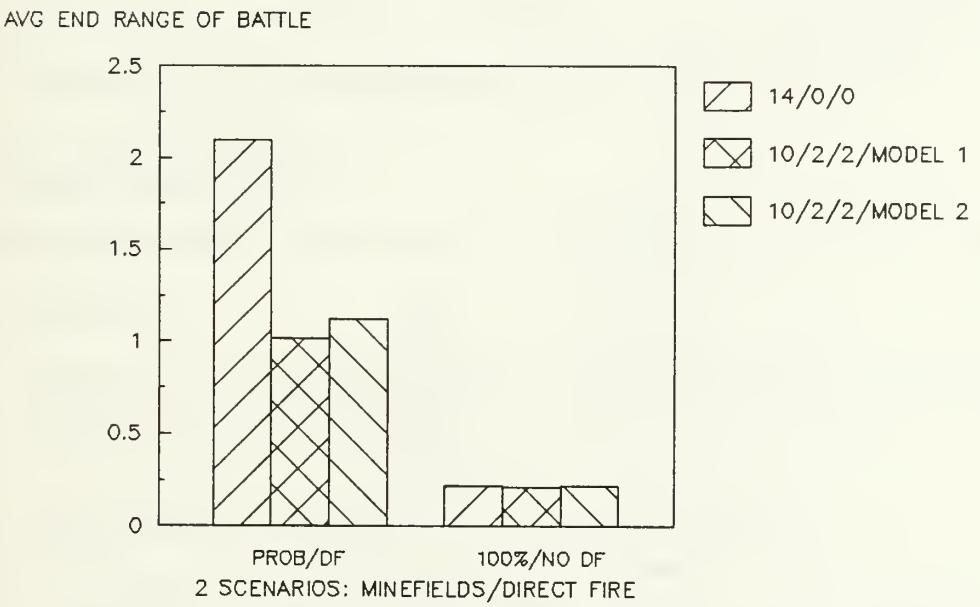


Figure 32. Model 1 versus Model 2
Measure of Effectiveness 10

MEASURE OF EFFECTIVENESS 11
MODEL 1 VERSUS MODEL 2

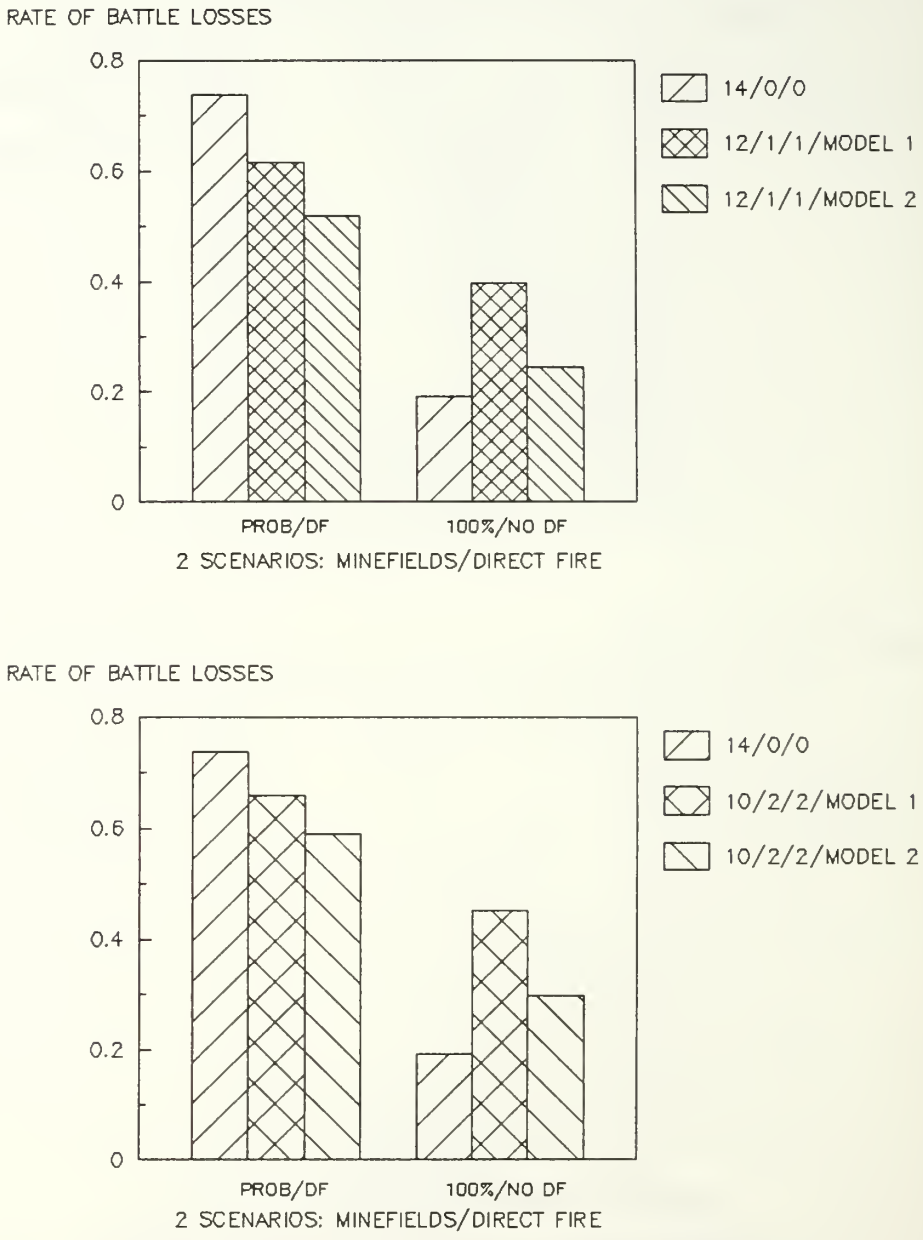


Figure 33. Model 1 versus Model 2
Measure of Effectiveness 11

V. SUMMARY, FUTURE ENHANCEMENTS, AND UTILIZATION

A. SUMMARY

The model, as developed, examines a limited number of different scenarios, tactics and equipment configurations. The combinations examined are by no means all encompassing. Continued analysis using the model as developed will provide answers to many mine/countermine questions concerning equipment and doctrine.

The model is a high resolution stochastically based simulation with a minimal amount of background routines to support the minefield breaching logic. While it will not answer all the questions concerning the basis of issue of countermine equipment, it does improve the analyst's ability to make decisions regarding the effectiveness of the mine/countermine equipment configurations.

B. FUTURE ENHANCEMENTS

The following additions or improvements to the model are recommended:

1. Addition of indirect fire to suppress both forces and allow smoke to be used to obscure the breaching sites through the minefields.

2. Development of a red movement network so a blue counterattack scenario may be examined.

3. A better method of controlling the breaching equipment during the conduct of the breach is required. At present the equipment must stay in the order input in the data file. Therefore if a unit has two mineplow tanks and a mineroller tank, and if the first mineplow clears a lane, the proofing vehicle would be a mineplow tank if it was entered

second in the file, as opposed to the mineroller tank as called for by doctrine.

4. A more accurate method of determining the destruction of a piece of breaching equipment is required. In the simulation, if one side of a mineplow or mineroller is rendered inoperable, then the entire system is considered lost. Additionally, the probability of surviving a mine detonation could be considered cumulative in nature, where the probability of surviving the first mine detonation to a breaching system may be higher than surviving the second etc.

5. The assumption of perfect knowledge concerning the extent of the minefield when it is identified does not accurately model the real world. A method of dealing with unclear or unknown boundaries of an obstacle must be developed to better simulate the actions of a unit encountering the minefield.

C. UTILIZATION

The model as it currently exists may be used to develop, examine and verify tactics. The placement of equipment within a formation, how far in the lead the mineroller should be placed and other tactics may be examined. Formations may dictate the number of breaching assets required. If the breaching equipment is in the forward platoons but not employed, they may encounter a minefield and be rendered inoperative prior to commencement of breaching operations. By changing the depths of the minefield, problems concerning the angle of attack on an obstacle may be examined.

The output generated by this model provides the appropriate information in the proper format required for more analytical models. One such model is a Semi-Markov

Renewal Process which aggregates high resolution data into various transition matrices. [Ref. 13]

Therefore, not only is the model useful as developed to investigate the issuance of countermine equipment, but may also be used in all areas concerning minefields and the tactics used to counter the obstacle.

APPENDIX A DEFINITION OF MODEL ONE VARIABLES

The variables used in Model 1 are defined below. All variables are either integer or single precision. The only double precision variable used in the model was the seed for the random number generator.

AAA -- Speed adjustment factor to maintain movement control.

ACTIVE1,ACTIVE2 -- The first 2 elements of a unit entering a minefield; they are the candidates for detonating a mine.

ANGLE -- Heading in radians of the arcs in the network.

ARC -- Line connecting 2 nodes, supporting the movement of the units.

AVE -- Avenue of approach, consisting of a series of arcs from the movement network.

BEHIND -- Binary variable; it is 1 when AAA is greater than 1; 0 otherwise.

BLUECODE,REDCODE -- Status code of the unit; for the blue force it may be; 0-defensive posture, 1-assault formation, 2-breaching formation. For the red force, if it equals 0 the unit is not combat effective.

BLUEDETECT1, REDDETECT1,2 -- The numerical identifier of the elements on the firer's detection list.

BLUENEGAGE,REDENGAGE -- Number of elements in one force detecting or engaging an element of the opposing force. Up to four blue elements may detect/engage a single red element while only two red elements may detect a single blue element.

BLUEPDET,REDPDET -- Probability of detecting an opposing element using the detection rate, DETRATE.

BLUERMAX,RMAX -- Maximum effective engagement ranges for the weapons systems; user input variables.

BLUESTATUS,REDSTATUS -- Indicates the current status of an element, the status may be: 0-element is dead, 1-element is in the detecting phase, 2-element is in the firing phase.

BLUEX1POS,BLUEY1POS -- Actual x,y coordinates of elements in each blue unit.

BLUEXOFF_,BLUEYOFF_ -- These values represent the offset distances in the x direction and y direction from the control vehicle. There is an x distance and a y distance for each of the three formations and are user input.

BLUEXPOS,BLUEYPOS -- Actual x,y coordinates of the control vehicle in each of the blue units.

BPHITS,BPKILL -- The probabilities associated with hitting and killing a red target using the range to delineate the probabilities.

BULL1,BULL2 -- Status indicators to determine if a unit is bulling through a minefield.

BVEHORDER -- An array which stores the order of the units as read from the data file.

BYPASS1,BYPASS2 -- Status indicators to determine if a unit is bypassing a minefield.

CLOCK -- Keeps track of the time of battle.

CLOSE -- Binary variable used in conjunction with the AAA variable.

CODE0 -- Records the time a unit goes to a defensive posture.

CV -- Crossing velocity; used in the detection module and represents the component of movement perpendicular to the target-observer line-of-sight.

DELX,DELY -- Represents the distance in the x and y directions the control vehicle moves during a single time step.

DENSMINE1,DENSMINE2 -- Represents the densities of the near and far minefields; it is user input.

DEPMINE1,DEPMINE2 -- The depth of a minefield, based on the maximum and minimum depth parameters and a Monte Carlo draw.

DETRATE -- The rate at which a detection can occur, used in calculation of the probability of detecting a vehicle.

DFKILL -- Counter to keep track of the number of direct fire kills per repetition.

DFTYPE -- Counter to keep track of the total number of direct fire kills by type over each repetition.

DIST -- Actual length of each arc; user input as part of the network.

DISTANCE -- Cumulative distance traveled along an arc.

DISTDET1,DISTDET2 -- Represents the distance to next detonation of a mine; used in both the initial entry to a minefield routine and during breaching operations.

ENTRY1,ENTRY2 -- Variables used to determine when a minefield has been entered.

EQUIP -- Used in the Unit Status subroutine to aid in tabulating types of equipment in the unit.

HEAD -- Head of an arc; a node number.

HEIGHT,RHEIGHT -- Represents the actual heights of the equipment in the various units; user input.

LAG -- User input value representing the maximum range deviation in the assaulting units.

LOC -- Represents the current arc location of the unit.

MAXDEPTH1,MAXDEPTH2 -- User input; the maximum depths of minefields 1 and 2.

MINDEPTH1,MINDEPTH2 -- User input; the minimum depths of minefields 1 and 2.

MINE1,MINE2 -- User input; the arcs on which the minefields located.

MINEDET1,MINEDET2 -- User input; the probabilities associated with detecting the presence of a minefield.

MINEKILL -- Counter to keep track of the number of kills due to mine detonations per repetition.

MINEPK -- User input; the probability that a mine kills a tank given detonation.

MOVE -- Cumulative distance indicator that keeps track of the distance a unit has moved through a minefield.

NARC -- Number of arcs in the network.

NNODE -- Number of nodes in the network.

NODE -- Specific number of a node.

NUMBLUE,NUMRED -- Number of blue elements per unit and the total number of red elements.

NUNIT -- Number of blue units in the simulation.

PDETONAT4 -- User input; the probability of a mine detonating when cleared by a breaching device.

PCLEAR4,PCLEAR5 -- Probabilities of a breaching device clearing a mine given an encounter.

PSURVIV4,PSURVIV5 -- Probabilities of surviving an encounter with a mine.

PDETTNK4,PDETTNK5 -- The cumulative probability of clearing a mine, either by the breaching device or detonation by the carrier.

PMINE1,PMINE2 -- User input; the probabilities of a minefield being emplaced, also interpreted the probabilities of encountering a minefield given it is emplaced.

PRCNTEFFB,PRCNTEFFR -- Used in the Unit Status subroutine, they keep track of the combat effectiveness of the units.

RANGE -- Range is calculated throughout the simulation and is the distance from blue element to red element.

REDX,REDY -- Represents the center of mass of the red position in the x,y plane.

REDXPOS,REDYPOS -- User input; the locations of the red elements in the x,y plane.

RNGADJ -- The calculated adjusted range to a target based on the range adjustment factors input into the detection model.

RNGAPP -- The calculated apparent range to a target based on the percent of the target that is visible to the observer.

RNGDET1,RNGDET2 -- Ranges to the detected elements in the blue force; used to determine which vehicles go on the red elements' detected list.

RNGMAX,RNGMIN -- At any given time step the blue units are in the interval [RNGMIN,RNGMAX] which is the distance from the enemy.

RPLOOK -- User input; the probability that a red element is looking in the direction of the target.

SPEED -- User input; the maximum speed each vehicle type is able to maintain on each arc based on terrain characteristics.

STATMIN1,STATMIN2 -- Binary variables; used to indicate the status of minefields.

TAU -- Terrain complexity code ranging from 1 to 7; used in the probability of detection equation.

RPHITM,RPKILL -- The probabilities associated with hitting and killing a blue target using range to delineate the probabilities.

PHIT,PKILL -- The actual values calculated from the table look-up which are then compared to a random number draw.

RRAF,RAF -- Range adjustment factors for the red and blue forces; used to calculated adjusted ranges for each target.

TDFKILL,TMINEKILL -- Total number of kills over the 50 repetitions due to direct fire and mines, respectively.

TPLOWKILL,TROLLKILL -- Total number of mineplows and minerollers killed over the 50 repetitions due to mine detonations. Thess represent only the breaching device being destroyed, not the carrier.

TPLOWBRCHKILL, TROLLBRCHKILL -- Total number of mineplow carriers and mineroller carriers killed by mine detonations over the 50 repetitions while conducting breaching operations.

TKILL -- Total number of kills due to all causes over a single repetition.

TTKILL -- A tabulating variable used in the output file, representing the total number of kills of all types over fifty repetitions.

UNIT -- Counter to track which is the current unit; the simulation will allow up to 10 units.

UNITSPD -- The speed the unit moves based on formation, location and equipment.

VEHTYPE,RVEHTYP -- These variables are coded for the type of vehicles in the units. The blue force has five types as discussed in Chapter 3 while the red force has two vehicle types; a BMP and a tank.

WIDTH -- The width is the effective width of the vehicle entering a minefield and is used in the calculation of the distance to a mine encounter.

XNODE,YNODE -- These values represent the X and Y grid coordinates of the nodes in the network.

XOFFPLT,YOFFPLT -- The x,y offsets used in the OFFSET subroutine to calculate the actual x,y coordinates.

APPENDIX B

COMPUTER PROGRAM LISTING

```
      * SIMULATION MAIN PROGRAM
      ********************  VARIABLE DECLARATION  **********************
  1         INTEGER   TAIL,HEAD,NODE,NNODE,ARC,BLUECODE,REDCODE,DEF
  2         INTEGER   AVE,START,NUNIT,LOC,NUMRED,REDENGAGE,STATMIN1,ENTRY1
  3         INTEGER   NARC,ISTART,LAST,UNIT,RED,REDSTATUS,VEHTYPE,RVEHTYP
  4         INTEGER   BLUESTATUS,ELEMENT,POSITION,NUMBLUE,CLOSE,BEHIND,REP
  5         INTEGER   REDDETECT1,REDDETECT2,BLUEENGAGE,BLUEDETECT1,MINE1
  6         INTEGER   BVEHORDER,BULL1,BULL2,BYPASS1,MINE2,STATMIN2,ENTRY2
  7         INTEGER   BYPASS2,MINEKILL,DFKILL,ROLLKILL,PLOWKILL,ROLLBRCHKILL
  8         INTEGER   TMINEKILL,TDFKILL,TROLLKILL,TPLOWKILL,TROLLBRCHKILL
  9         INTEGER   PLOWBRCHKILL,TPLOWBRCHKILL,TKILL,TTKILL,DFTYPE,MTYPE
 10         REAL  WIDTH,DIST,ANGLE,XNODE,YNODE,CLOCK,SP,BLUEXOFF1,BLUEYOFF1
 11         REAL  BLUEXOFF2,BLUEYOFF2,BLUEX1POS,BLUEY1POS,REDXPOS,REDYPOS
 12         REAL  BLUEXOFF0,BLUEYOFF0,MINDEPTH1,MAXDEPTH1,RNG,CODE0
 13         REAL  DELX,DELY,TRAVEL,SPEED,DISTANCE,CV,UNITSPD,RHEIGHT,RRAF
 14         REAL  RPLOOK,REDX,REDY,BLUEXPOS,BLUEYPOS,LAG,AAA,RMAX
 15         REAL  DENSMINE1,PMINE1,DISTDET1,DEPMINE1,MINDEPTH2,MAXDEPTH2
 16         REAL  BLUERMAX,DENSMINE2,PMINE2,DISTDET2,DEPMINE2
 17         REAL  RPHITS,RPHITM,RPKILL,BPHITS,BPKILL
 18         REAL*8  DSEED
 19         DIMENSION TAIL(150),HEAD(150),TIME(150),AVE(10,30),BULL1(10)
 20         DIMENSION FLOW(100),DIST(100),WIDTH(100),ISTART(10),BYPASS1(10)
 21         DIMENSION ARC(100),SP(100),ANGLE(100),DISTANCE(10),CV(10)
 22         DIMENSION NODE(150),XNODE(150),YNODE(150),BLUEDETECT1(10,20)
 23         DIMENSION BLUEXPOS(20),BLUEYPOS(20),RHEIGHT(30),RRAF(30),RMAX(30)
 24         DIMENSION SPEED(10,80),BLUEYOFF1(20),BLUEXOFF1(20),LOC(10)
 25         DIMENSION BLUEXOFF2(20),BLUEYOFF2(20),RVEHTYP(30),BLUECODE(10)
 26         DIMENSION BLUEXOFF0(20),BLUEYOFF0(20),STATMIN1(10),MINE1(10)
 27         DIMENSION BLUEX1POS(10,20),BLUEY1POS(10,20),BLUESTATUS(10,20)
 28         DIMENSION REDXPOS(50),REDYPOS(50),RPLOOK(10,50),UNITSPD(10)
 29         DIMENSION RED(50),REDSTATUS(30),VEHTYPE(10,20),REDENGAGE(100)
 30         DIMENSION REDDETECT1(30),REDDETECT2(30),BLUEENGAGE(30),MINE2(10)
 31         DIMENSION PMINE2(10),DISTDET2(10,100),DEPMINE2(10),ENTRY2(10)
 32         DIMENSION PMINE1(10),DISTDET1(10,100),DEPMINE1(10),ENTRY1(10)
 33         DIMENSION RPHITS(10),RPHITM(10),RPKILL(10),BPHITS(10),BPKILL(10)
 34         DIMENSION BVEHORDER(10,20),RNG(20),STATMIN2(10),BYPASS2(10)
 35         DIMENSION BULL2(10),MINEKILL(100),DFKILL(100),ROLLKILL(100)
 36         DIMENSION PLOWKILL(100),ROLLBRCHKILL(100),PLOWBRCHKILL(100)
 37         DIMENSION BLUERMAX(10,20),DFTYPE(20),MTYPE(20),CODE0(10),DEF(10)
      *
 38            OPEN (UNIT = 54 , FILE = 'SIMUL')
 39            OPEN (UNIT = 44 , FILE = 'RESULTS')
 40            OPEN (UNIT = 34 , FILE = 'OUTPUT')
 41            OPEN (UNIT = 24 , FILE = 'MINETIME')
 42            OPEN (UNIT = 23 , FILE = 'TIMEMINE')

      ************************  SET INITIAL OPTIONS  ***************************

      *
      *               SET START NODE
 43           START = 1
      *               SET LAST NODE
 44           LAST   = 29
      *               TOTAL NUMBER OF ARCS IN THE SECTOR
 45           NARC   = 31
      *               TOTAL NUMBER OF NODES IN THE SECTOR
 46           NNODE  = 29
      *               NUMBER OF AVENUES OF APPROACH
```

```
47          NUNIT = 4
    *             NUMBER OF RED ELEMENTS
48          NUMRED = 13
    *             NUMBER OF BLUE ELEMENTS IN EACH UNIT
49           NUMBLUE=14

    *   SET INITIAL CONDITIONS
    *SET RANDOM NUMBER SEED
50              DSEED=1029395.D0


    *SET TERRAIN CODE
51              TAU = 3.5


    *
    ************  READ DATA FROM DATA FILES  ************************
    *
52        READ(1,100) (ARC(I),TAIL(I),HEAD(I),DIST(I),ANGLE(I),I=1,NARC)
53  100   FORMAT(2X,I3,3X,I2,3X,I2,4X,F4.2,3X,F5.3)
54        READ(2,200) (NODE(I),XNODE(I),YNODE(I),I=1,NNODE)
55  200   FORMAT(2X,I3,2X,F5.0,1X,F5.0)

56        READ(3,300)((AVE(K,I),K=1,4),I=1,13)
57  300   FORMAT(2X,I3,2X,I3,2X,I3,2X,I3)

58        READ(4,400)((SPEED(K,I),K=1,5),I=1,NARC)
59  400   FORMAT(2X,5F4.0)

60        READ(9,500) (BLUEXOFF0(I),BLUEYOFF0(I),I=1,NUMBLUE)
61        READ(10,500) (BLUEXOFF1(I),BLUEYOFF1(I),I=1,NUMBLUE)
62        READ(11,500) (BLUEXOFF2(I),BLUEYOFF2(I),I=1,NUMBLUE)
63  500   FORMAT(2X,F5.2,2X,F5.2)

64        READ(17,550) (BPHITS(I),BPKILL(I),I=1,8)
65  550   FORMAT(2X,F4.2,2X,F4.2)

66        READ(12,600) (RED(I),REDXPOS(I),REDYPOS(I),I=1,NUMRED)
67  600   FORMAT (2X,I2,2X,F5.1,2X,F5.1)

68        READ(13,700) ((RPLOOK(K,I),K=1,NUNIT),I=1,NUMRED)
69  700   FORMAT(2X,4F6.2)

70        READ(14,800) ((BVEHORDER(K,I),K=1,NUNIT),I=1,NUMBLUE)
71  800   FORMAT(2X,I1,2X,I1,2X,I1,2X,I1)

72        READ(15,900) (RVEHTYP(I),RHEIGHT(I),RRAF(I),RMAX(I),I=1,NUMRED)
73  900   FORMAT(2X,I1,2X,F3.1,2X,F3.1,2X,F3.1)

74        READ(16,950) (RPHITS(I),RPHITM(I),RPKILL(I),I=1,9)
75  950   FORMAT(2X,F4.2,2X,F4.2,2X,F4.2)


76            TROLLBRCHKILL=0
77            TPLOWBRCHKILL=0
78            TMINEKILL=0
79            TDFKILL=0
80            TROLLKILL=0
81            TPLOWKILL=0
```

```
 82          DO 181 REP=1,50

 83           WRITE(54,928) REP
 84 928       FORMAT('**********  REPITITION NUMBER ',I3' **********')

    ************************************************************************
    *     START SIMULATION

 85           RNGMIN = 20.0

 86           MINEKILL(REP)=0
 87           DFKILL(REP)=0
 88           DFTYPE(1)=0
 89           DFTYPE(2)=0
 90           DFTYPE(3)=0
 91           DFTYPE(4)=0
 92           DFTYPE(5)=0
 93           MTYPE(1)=0
 94           MTYPE(2)=0
 95           MTYPE(3)=0
 96           PLOWKILL(REP)=0
 97           ROLLKILL(REP)=0
 98           ROLLBRCHKILL(REP)=0
 99           PLOWBRCHKILL(REP)=0

100          CLOCK = 0.0
101          REDX=XNODE(26)
102          REDY=YNODE(26)
103          REDCODE = 1


    *MINEFIELD NUMBER 1 LOCATIONS
104          MINE1(1)=10
105          MINE1(2)=9
106          MINE1(3)=17
107          MINE1(4)=22
108          MINDEPTH1=150
109          MAXDEPTH1=300
110          DENSMINE1=.003
111          PMINE1(1)=0.70
112          PMINE1(2)=0.70
113          PMINE1(3)=0.70
114          PMINE1(4)=0.70

    *MINEFIELD NUMBER 2 LOCATIONS
115          MINE2(1)=13
116          MINE2(2)=12
117          MINE2(3)=26
118          MINE2(4)=24
119          MINDEPTH2=200
120          MAXDEPTH2=300
121          DENSMINE2=.02
122          PMINE2(1)=0.90
123          PMINE2(2)=0.90
124          PMINE2(3)=0.90
125          PMINE2(4)=0.90

126         DO 40 UNIT=1,NUNIT
127          BLUECODE(UNIT) = 1
```

```
128             DEF(UNIT)=0
129             CODE0(UNIT)=0
130             ISTART(UNIT)=1
131             LOC(UNIT)=AVE(UNIT,1)
132             BLUEXPOS(UNIT) = XNODE(TAIL(LOC(UNIT)))
133             BLUEYPOS(UNIT) = YNODE(TAIL(LOC(UNIT)))
134             DISTANCE(UNIT)=0.0
135             UNITSPD(UNIT)=0.0
136             STATMIN1(UNIT)=0
137             STATMIN2(UNIT)=0
138             ENTRY1(UNIT)=0
139             ENTRY2(UNIT)=0
140             BULL1(UNIT)=0
141             BYPASS1(UNIT)=0
142             BULL2(UNIT)=0
143             BYPASS2(UNIT)=0
144          DO 47  POSITION=1,NUMBLUE
145             VEHTYPE(UNIT,POSITION)=BVEHORDER(UNIT,POSITION)
146             BLUESTATUS(UNIT,POSITION)=1
147             REDENGAGE((NUMBLUE*(UNIT-1))+POSITION)=0

    ***************BLUE MAX ENGAGEMENT RANGE*****************
148             BLUERMAX(UNIT,POSITION)= 3.0

149 47       CONTINUE
150 40       CONTINUE

151          DO 13 ELEMENT=1,NUMRED

152             REDSTATUS(ELEMENT)=1
153             BLUEENGAGE(ELEMENT)=0
154 13      CONTINUE

    ********      SIMULATION START     *****************


155             CALL MINESETUP (UNIT,NUNIT,DSEED,PMINE1,
        *              STATMIN1,MINDEPTH1,MAXDEPTH1,DEPMINE1,DENSMINE1,
        *              DISTDET1,PMINE2,STATMIN2,MINDEPTH2,MAXDEPTH2,
        *              DEPMINE2,DENSMINE2,DISTDET2)

156        DO 20 J=1,200
157                CLOCK=CLOCK+.5


158           CALL UNITSTATUS(BLUECODE,REDCODE,UNIT,NUNIT,POSITION,NUMBLUE,
        *           BLUESTATUS,REDSTATUS,NUMRED,ELEMENT,VEHTYPE,CLOCK,REP,
        *           RNGMIN)

    * CHECKS TO DETERMINE IF BATTLE TERMINATION CRITERIA HAS BEEN MET

159                IF (REDCODE .EQ. 0) GO TO 179
160           CALL LOCATION ( LAG,UNIT,NUNIT,BLUEXPOS,BLUEYPOS,RNG,
        *                  RNGMIN,REDX,REDY,AAA,CLOSE,BEHIND,BLUECODE)

161               IF(RNGMIN .LT. .250) THEN
162           CALL UNITSTATUS(BLUECODE,REDCODE,UNIT,NUNIT,POSITION,NUMBLUE,
        *           BLUESTATUS,REDSTATUS;NUMRED,ELEMENT,VEHTYPE,CLOCK,REP,
        *           RNGMIN)
163                END IF
```

```
164                IF(RNGMIN .LT. .250) GO TO 179

    * ENTER MOVEMENT ROUTINE
165           DO 30 UNIT=1,NUNIT

    *CHECK TO SEE IF UNIT HAS ENTERED MINEFIELD; 30 SECOND MOVEMENT DELAY
166                IF(ENTRY1(UNIT) .EQ. 1) THEN
167                     ENTRY1(UNIT)=2
168                     GO TO 30
169                END IF
170                IF(ENTRY2(UNIT) .EQ. 1) THEN
171                     ENTRY2(UNIT)=2
172                     GO TO 30
173                END IF

174             CALL MOV1 (LOC,TAIL,XNODE,YNODE,SPEED,TRAVEL,ANGLE,AVE,DIST,
          *            NODE,ISTART,DISTANCE,BLUEXPOS,BLUEYPOS,CLOCK,UNIT,
          *            BLUEXOFF1,BLUEYOFF1,BLUEXOFF2,BLUEYOFF2,ENTRY1,
          *            BLUEX1POS,BLUEY1POS,UNITSPD,NUMBLUE,VEHTYPE,AAA,
          *            CLOSE,BEHIND,BLUECODE,BLUEXOFF0,BLUEYOFF0,DEPMINE1,
          *            MINE1,STATMIN1,DSEED,BLUESTATUS,DISTDET1,REDX,REDY,
          *            BLUEDETECT1,RNG,BULL1,BYPASS1,ENTRY2,DEPMINE2,MINE2,
          *            STATMIN2,DISTDET2,BULL2,BYPASS2,MINEKILL,ROLLKILL,
          *            PLOWKILL,ROLLBRCHKILL,PLOWBRCHKILL,REP,MTYPE)
175 30         CONTINUE

    * RED DETECT/FIRE ROUTINE ENTERED
176           DO 43 ELEMENT=1,NUMRED
177               IF (REDSTATUS(ELEMENT) .EQ. 0) THEN
178                     GO TO 43
179               ELSE IF (REDSTATUS(ELEMENT) .EQ. 2) THEN

180          CALL REDFIRE(REDSTATUS,ELEMENT,REDENGAGE,BLUESTATUS,UNIT,
          *            POSITION,NUMBLUE,REDXPOS,REDYPOS,NUNIT,VEHTYPE,
          *            REDDETECT1,REDDETECT2,BLUEX1POS,BLUEY1POS,DSEED,CLOCK,
          *            RVEHTYP,RPHITS,RPHITM,RPKILL,DFKILL,REP,DFTYPE)
181                GO TO 43
182               END IF

183             CALL REDDETECT (REDXPOS,REDYPOS,BLUEXPOS,BLUEYPOS,
          *              BLUEX1POS,BLUEY1POS,NUNIT,REDENGAGE,BLUESTATUS,
          *              ANGLE,UNIT,UNITSPD,CLOCK,LOC,CV,NUMRED,NUMBLUE,
          *              REDX,REDY,RED,RPLOOK,REDSTATUS,DSEED,VEHTYPE,
          *              REDDETECT1,REDDETECT2,ELEMENT,POSITION,TAU,RVEHTYP,
          *              BLUECODE,RMAX)

184 43       CONTINUE

    * BLUE DETECT/FIRE ROUTINE ENTERED
185           DO 63 UNIT=1,NUNIT
186              DO 69 POSITION=1,NUMBLUE
187               IF (BLUESTATUS(UNIT,POSITION) .EQ. 0) THEN
188                     GO TO 69
189               ELSE IF (VEHTYPE(UNIT,POSITION) .EQ. 4 .OR.
          *                    VEHTYPE(UNIT,POSITION) .EQ. 5) THEN
190                     GO TO 69
191               ELSE IF (BLUESTATUS(UNIT,POSITION) .EQ. 2) THEN
```

```
192       CALL BLUEFIRE(REDSTATUS,ELEMENT,BLUEENGAGE,BLUESTATUS,UNIT,
         *             POSITION,REDXPOS,REDYPOS,RVEHTYP,
         *             BLUEDETECT1,BLUEX1POS,BLUEY1POS,DSEED,
         *             CLOCK,BPHITS,BPKILL)
193               GO TO 69
194              END IF

195          CALL BLUEDETECT (REDXPOS,REDYPOS,BLUEX1POS,BLUEY1POS,
         *          BLUEENGAGE,BLUESTATUS,REDSTATUS,DSEED,UNIT,CLOCK,NUMRED,
         *          BLUEDETECT1,ELEMENT,POSITION,TAU,RVEHTYP,RHEIGHT,RRAF,
         *          BLUERMAX)

196 69       CONTINUE
197 63       CONTINUE

    *CHECK TO SEE TIME UNIT GOES TO DEFENSIVE POSTURE
198            DO 159 UNIT=1,NUNIT
199                 IF (BLUECODE(UNIT) .EQ. 0 .AND. DEF(UNIT) .EQ. 0) THEN
200                         CODE0(UNIT) = CLOCK
201                         DEF(UNIT) = 1
202                 END IF
203 159        CONTINUE
204 20     CONTINUE

    * RUNNING TOTAL OF LOSSES
205 179             TDFKILL=TDFKILL+DFKILL(REP)
206                 TMINEKILL=TMINEKILL+MINEKILL(REP)
207                 TROLLKILL=TROLLKILL+ROLLKILL(REP)
208                 TPLOWKILL=TPLOWKILL+PLOWKILL(REP)
209                 TROLLBRCHKILL=TROLLBRCHKILL+ROLLBRCHKILL(REP)
210                 TPLOWBRCHKILL=TPLOWBRCHKILL+PLOWBRCHKILL(REP)
211                 TKILL=DFKILL(REP)+MINEKILL(REP)+ROLLBRCHKILL(REP)+
         *                              PLOWBRCHKILL(REP)

212          WRITE(44,338) DFKILL(REP),DFTYPE(1),(DFTYPE(2)+DFTYPE(4)),
         *       (DFTYPE(3)+DFTYPE(5)),ROLLKILL(REP),PLOWKILL(REP),
         *       MINEKILL(REP),MTYPE(1),MTYPE(2),MTYPE(3),
         *       PLOWBRCHKILL(REP),ROLLBRCHKILL(REP),TKILL,CLOCK,RNGMIN
213 338      FORMAT(I2,'/',I2,'/',I2,'/',I2,1X,I2,4X,I2,3X,I2,'/',
         *              I2,'/',I2,'/',I2,4X,I2,7X,I2,6X,I3,4X,F4.1,2X,F6.3)
214          WRITE(34,377) DFKILL(REP),DFTYPE(1),(DFTYPE(2)+DFTYPE(4)),
         *          (DFTYPE(3)+DFTYPE(5)),ROLLKILL(REP),PLOWKILL(REP),
         *          MINEKILL(REP),MTYPE(1),MTYPE(2),MTYPE(3),
         *          PLOWBRCHKILL(REP),ROLLBRCHKILL(REP),TKILL,CLOCK,RNGMIN
215 377      FORMAT(2X,13I4,2X,F4.1,2X,F5.3)
216          WRITE(24,577) STATMIN1(1),STATMIN2(1),CODE0(1),
         *                 STATMIN1(2),STATMIN2(2),CODE0(2),
         *                 STATMIN1(3),STATMIN2(3),CODE0(3),
         *                 STATMIN1(4),STATMIN2(4),CODE0(4),CLOCK
217          WRITE(23,577) STATMIN1(1),STATMIN2(1),CODE0(1),
         *                 STATMIN1(2),STATMIN2(2),CODE0(2),
         *                 STATMIN1(3),STATMIN2(3),CODE0(3),
         *                 STATMIN1(4),STATMIN2(4),CODE0(4),CLOCK
218 577      FORMAT(2X,2I4,F5.1,2X,2I4,F5.1,2X,2I4,F5.1,2X,2I4,F5.1,2X,F5.1)



219 181    CONTINUE
```

```
220           TTKILL=TDFKILL+TMINEKILL+TROLLBRCHKILL+TPLOWBRCHKILL

221           WRITE(44,333)
222 333       FORMAT('TOTAL NUMBER OF KILLS BY CATEGORY')
223           WRITE(44,334)
224 334       FORMAT('DIRECTFIRE    ROLL   PLOW   MINE   PLOWCARRIER ',
      *              '   ROLLCARRIER   TOTALKILLS')
225           WRITE(44,335) TDFKILL,TROLLKILL,TPLOWKILL,TMINEKILL,
      *                                 TPLOWBRCHKILL,TROLLBRCHKILL,TTKILL
226 335       FORMAT(5X,I3,4X,I3,3X,I3,3X,I3,7X,I3,11X,I3,11X,I3)


227           STOP
228           END
    ******************************************************************
```

```
    ****************  MINESETUP ************************************

229       SUBROUTINE MINESETUP (UNIT,NUNIT,DSEED,PMINE1,
          *              STATMIN1,MINDEPTH1,MAXDEPTH1,DEPMINE1,DENSMINE1,
          *              DISTDET1,PMINE2,STATMIN2,MINDEPTH2,MAXDEPTH2,
          *              DEPMINE2,DENSMINE2,DISTDET2)
230         INTEGER  UNIT,NUNIT,STATMIN1,STATMIN2,PACE
231         REAL  RNDMINE,PMINE1,MINDEPTH1,MAXDEPTH1,DEPMINE1,DENSMINE1
232         REAL  PMINE2,MINDEPTH2,MAXDEPTH2,DEPMINE2,DENSMINE2
233         REAL  DISTDET1,DISTDET2,WIDTH
234         REAL*8  DSEED
235         DIMENSION  RNDMINE(100),PMINE1(10),STATMIN1(10),DISTDET1(10,100)
236         DIMENSION  PMINE2(10),STATMIN2(10),DISTDET2(10,100)
237         DIMENSION  DEPMINE1(10),DEPMINE2(10)

    * EFFECTIVE WIDTH OF M1
238         WIDTH=3.5


239               DO 31 UNIT=1,NUNIT
240                   CALL GGUBS (DSEED,90,RNDMINE)
    *  DETERMINE STATUS OF MINEFIELD1
241                   IF(RNDMINE(1) .LT. PMINE1(UNIT)) THEN
242                         STATMIN1(UNIT)=1
    *DETERMINE DEPTH OF MINEFIELD1
243         DEPMINE1(UNIT)=(MINDEPTH1+((MAXDEPTH1-MINDEPTH1)
          *                                    *RNDMINE(2)))/1000
244                   END IF

    *SET UP ARRAY OF DISTANCES TO MINE ENCOUNTERS
245                   IF (STATMIN1(UNIT) .EQ. 1) THEN
246                       DO 32 PACE=1,88
247        DISTDET1(UNIT,PACE)=((LOG(1-RNDMINE(PACE+2)))
          *                              /((-WIDTH*DENSMINE1)))/1000
248                 IF (DISTDET1(UNIT,PACE) .GT. DEPMINE1(UNIT)) THEN
249                         DISTDET1(UNIT,PACE) = DEPMINE1(UNIT)/2
250                   END IF
251 32          CONTINUE
252                   END IF

253             WRITE(54,967) UNIT,STATMIN1(UNIT),DEPMINE1(UNIT),RNDMINE(2)
254 967         FORMAT('UNIT',I2,' STATUSMINE1 ',I3,' DEPTH OF FIELD ',F5.3,
          *                       ' RNDNUM ',F5.3)


    * REPEAT ABOVE PROCEDURES FOR MINEFIELD2
255                   CALL GGUBS (DSEED,90,RNDMINE)
256                   IF(RNDMINE(1) .LT. PMINE2(UNIT)) THEN
257                         STATMIN2(UNIT)=1
258         DEPMINE2(UNIT)=(MINDEPTH2+((MAXDEPTH2-MINDEPTH2)
          *                                    *RNDMINE(2)))/1000
259                   END IF
260                   IF (STATMIN2(UNIT) .EQ. 1) THEN
261                       DO 21 PACE=1,88
262        DISTDET2(UNIT,PACE)=((LOG(1-RNDMINE(PACE+2)))
          *                              /((-WIDTH*DENSMINE2)))/1000
263                 IF (DISTDET2(UNIT,PACE) .GT. DEPMINE2(UNIT)) THEN
264                         DISTDET2(UNIT,PACE) = DEPMINE2(UNIT)/2
265                   END IF
266 21          CONTINUE
267                   END IF

268             WRITE(54,977) UNIT,STATMIN2(UNIT),DEPMINE2(UNIT),RNDMINE(2)
269 977         FORMAT('UNIT',I2,' STATUSMINE2 ',I3,' DEPTH OF FIELD ',F5.3,
          *                       ' RNDNUM ',F5.3)
270 31          CONTINUE

271         RETURN
272         END
    ************************************************************************
```

```
    ****************** UNITSTATUS  ************************************

273           SUBROUTINE UNITSTATUS(BLUECODE,REDCODE,UNIT,NUNIT,POSITION,
          *     NUMBLUE,BLUESTATUS,REDSTATUS,NUMRED,ELEMENT,VEHTYPE,CLOCK,REP,
          *     RNGMIN)
274           INTEGER BLUECODE,REDCODE,UNIT,NUNIT,POSITION,NUMBLUE,EQUIP
275           INTEGER BLUESTATUS,REDSTATUS,NUMRED,ELEMENT,VEHTYPE,REP
276           REAL    PRCNTEFFB,PRCNTEFFR,SURVIV,RSURVIV,CLOCK,RNGMIN
277           DIMENSION SURVIV(10),BLUESTATUS(10,20),REDSTATUS(30)
278           DIMENSION BLUECODE(10),VEHTYPE(10,20),EQUIP(10,10),PRCNTEFFB(10)


    *D DETERMINE CURRENT STATUS OF RED AND BLUE FORCES
279                 RSURVIV = 0
280            DO 42 UNIT=1,NUNIT
281                 SURVIV(UNIT) = 0
282                DO 36 J=1,10
283                     EQUIP(UNIT,J) = 0
284 36              CONTINUE
285                DO 44 POSITION = 1,NUMBLUE
286                   IF (BLUESTATUS(UNIT,POSITION) .NE. 0) THEN
287                               SURVIV(UNIT) = SURVIV(UNIT) + 1
288                     IF (VEHTYPE(UNIT,POSITION) .EQ. 1) THEN
289           EQUIP(UNIT,VEHTYPE(UNIT,POSITION))
          *                        = EQUIP(UNIT,VEHTYPE(UNIT,POSITION))+1
290                   ELSE IF (VEHTYPE(UNIT,POSITION) .EQ. 2) THEN
291           EQUIP(UNIT,VEHTYPE(UNIT,POSITION))
          *                        = EQUIP(UNIT,VEHTYPE(UNIT,POSITION))+1
292                   ELSE IF (VEHTYPE(UNIT,POSITION) .EQ. 3) THEN
293           EQUIP(UNIT,VEHTYPE(UNIT,POSITION))
          *                        = EQUIP(UNIT,VEHTYPE(UNIT,POSITION))+1
294                   ELSE IF (VEHTYPE(UNIT,POSITION) .EQ. 4) THEN
295           EQUIP(UNIT,VEHTYPE(UNIT,POSITION))
          *                        = EQUIP(UNIT,VEHTYPE(UNIT,POSITION))+1
296                   ELSE IF (VEHTYPE(UNIT,POSITION) .EQ. 5) THEN
297           EQUIP(UNIT,VEHTYPE(UNIT,POSITION))
          *                        = EQUIP(UNIT,VEHTYPE(UNIT,POSITION))+1
298                   END IF
299                 END IF
300 44              CONTINUE

    * CHECK TO SET IF BLUE UNIT HAS REACHED DEFENSIVE POSTURE CRITERIA
301            PRCNTEFFB(UNIT) = SURVIV(UNIT)/NUMBLUE
302                   IF (PRCNTEFFB(UNIT) .LT. .5) THEN
303                         BLUECODE(UNIT) = 0
304                   END IF

305 42         CONTINUE
```

```
    * TABULATION OF RED STRNGTH
306           DO 89 ELEMENT=1,NUMRED
307               IF(REDSTATUS(ELEMENT) .NE. 0) THEN
308                     RSURVIV = RSURVIV + 1
309               END IF
310 89        CONTINUE
311                    PRCNTEFFR = RSURVIV/NUMRED
312               IF (PRCNTEFFR .LT. .250) THEN
313                    REDCODE = 0

314               END IF

    * WRITE OUTPUT TO DATA FILES
315           IF (CLOCK .LT. 1.0 .OR. PRCNTEFFR .LT. .250
      *                              .OR. RNGMIN .LT. .250) THEN
316             DO 19 UNIT=1,NUNIT
317               WRITE(54,987) UNIT,BLUECODE(UNIT),EQUIP(UNIT,1),
      *              EQUIP(UNIT,2),EQUIP(UNIT,4),EQUIP(UNIT,3),EQUIP(UNIT,5)
318 987             FORMAT('UNIT ',I1,' UNITCODE ',I1,' EQUIP TANK ',
      *                        I2,' MINEPLOW ' ,2I4,' MINEROLLER',2I4)
319 19          CONTINUE

320           IF (REP .EQ. 1 .AND. CLOCK .LT. 1.0) THEN
321             DO 109 UNIT=1,NUNIT
322               WRITE(44,387) UNIT,BLUECODE(UNIT),EQUIP(UNIT,1),
      *              EQUIP(UNIT,2),EQUIP(UNIT,4),EQUIP(UNIT,3),EQUIP(UNIT,5)
323 387             FORMAT('UNIT ',I1,' UNITCODE ',I1,' EQUIP TANK ',
      *                        I2,' MINEPLOW ' ,2I4,' MINEROLLER',2I4)
324 109          CONTINUE

325           WRITE(44,336)
326 336       FORMAT('NUMBER OF KILLS BY CATEGORY PER REPITITION')
327           WRITE(44,337)
328 337       FORMAT(' DIRECTFIRE ROLL  PLOW  MINEFIELD  PLOWCARR',
      *                    ' ROLLCARR  TOTKILL CLOCK MINRNG')
329           WRITE(24,537)
330 537       FORMAT(10X,'ACTIVE MINEFIELDS AND TIMES TO DEFENSIVE POSTURE')
331           WRITE(24,538)
332 538       FORMAT(5X,'AVENUE 1',5X,'  AVENUE 2',5X,'  AVENUE 3',5X,
      *                '  AVENUE 4',3X,'RUN TIME')
333           WRITE(24,539)
334 539       FORMAT('     M1  M2         M1  M2         M1  M2',
      *                       '         M1  M2')


335           END IF

336            WRITE(54,717) RSURVIV,REDCODE,PRCNTEFFR
337 717        FORMAT( 'RED UNIT #SURVIV ',F3.0,' UNITCODE ',I2,' %EFF',F5.3)
338           END IF
339           RETURN
340            END

    ******************************************************************
```

```
      **********LOCATION**********

341         SUBROUTINE LOCATION (LAG,UNIT,NUNIT,BLUEXPOS,BLUEYPOS,
           *                RNG,RNGMIN,REDX,REDY,AAA,CLOSE,BEHIND,BLUECODE)
342           INTEGER UNIT,NUNIT,CLOSE,BEHIND,BLUECODE
343           REAL LAG,BLUEXPOS,BLUEYPOS,REDX,REDY,RNG,RNGMIN,RNGMAX,AAA
344           DIMENSION  BLUEXPOS(20),BLUEYPOS(20),RNG(20),BLUECODE(10)

345                LAG = 0.5
346                RNGMIN = 20.0
347                RNGMAX =  0.1
348                CLOSE = 0
349                BEHIND = 0


      * CHECK TO DETERMINE IF UNITS ARE ALIGNED
350                 DO 57 UNIT=1,NUNIT
351           RNG(UNIT)=(SQRT(((REDX-BLUEXPOS(UNIT))**2)+
           *           ((REDY-BLUEYPOS(UNIT))**2)))/10
352                IF (BLUECODE(UNIT) .EQ. 0) THEN
353                     GO TO 57
354                END IF
355               IF (RNG(UNIT) .LT. RNGMIN ) THEN
356                    RNGMIN = RNG(UNIT)
357                    CLOSE=UNIT
358                END IF

359               IF (RNG(UNIT) .GT. RNGMAX ) THEN
360                    RNGMAX = RNG(UNIT)
361                END IF
362 57        CONTINUE

      * CALCULATE THE LAG FACTOR AAA
363               IF((RNGMAX - RNGMIN) .GT. LAG) THEN
364                     AAA = (RNGMAX-RNGMIN)/LAG
365                     BEHIND = 1
366                END IF
367           RETURN
368           END

      **********
```

```
**********          MOV1     ************************************

369       SUBROUTINE MOV1 (LOC,TAIL,XNODE,YNODE,SPEED,TRAVEL,ANGLE,AVE,DIST,
         *          NODE,ISTART,DISTANCE,BLUEXPOS,BLUEYPOS,CLOCK,UNIT,
         *          BLUEXOFF1,BLUEYOFF1,BLUEXOFF2,BLUEYOFF2,ENTRY1,
         *          BLUE1POS,BLUEY1POS,UNITSPD,NUMBLUE,VEHTYPE,AAA,
         *          CLOSE,BEHIND,BLUECODE,BLUEXOFF0,BLUEYOFF0,DEPMINE1,
         *          MINE1,STATMIN1,DSEED,BLUESTATUS,DISTDET1,REDX,REDY,
         *          BLUEDETECT1,RNG,BULL1,BYPASS1,ENTRY2,DEPMINE2,MINE2,
         *          STATMIN2,DISTDET2,BULL2,BYPASS2,MINEKILL,ROLLKILL,
         *          PLOWKILL,ROLLBRCHKILL,PLOWBRCHKILL,REP,MTYPE)
370         INTEGER  TAIL,NODE,LOC,ISTART,UNIT,CLOSE,BEHIND,ENTRY1,MINE1
371         INTEGER  NNODE,AVE,VEHTYPE,NUMBLUE,BLUECODE,STATMIN1,BLUESTATUS
372         INTEGER  ACTIVE1,ACTIVE2,CLEAR,PSN,BLUEDETECT1,BULL1,BYPASS1
373         INTEGER  ENTRY2,MINE2,STATMIN2,BULL2,BYPASS2,MINEKILL,ROLLKILL
374         INTEGER  TEMPTYPE,TEMPSTATUS,TEMPDETECT,PLOWKILL,PLOWBRCHKILL,REP
375         INTEGER  ROLLBRCHKILL,MTYPE
376         REAL     DIST,SPEED,DISTANCE,BLUEXPOS,BLUEYPOS,MINEDET,REDX
377         REAL     BLUEXOFF1,BLUYOFF1,BLUEXOFF2,BLUEYOFF2,DISTDET1,REDY
378         REAL     BLUE1POS,BLUEY1POS,BLUEXOFF0,BLUEYOFF0,WIDTH,STEPMINE1
379         REAL     XNODE,YNODE,ANGLE,UNITSPD,AAA,DENSITY,MINERND,STEPMINE2
380         REAL     MINEPK,MOVE,DEPMINE1,RNG,DEPMINE2,DISTDET2,MINEDET2
381         REAL     MINEDET1,PDETONAT4
382         REAL*8     DSEED
383         DIMENSION  TAIL(150),NODE(150),LOC(10),BLUEDETECT1(10,20)
384         DIMENSION  DIST(100),AVE(10,30),SPEED(10,80),DISTDET1(10,100)
385         DIMENSION  ANGLE(100),DISTANCE(10),ISTART(10),WIDTH(10),RNG(20)
386         DIMENSION  XNODE(150),YNODE(150),BLUEXPOS(20),BLUEYPOS(20)
387         DIMENSION  BLUEXOFF1(20),BLUEYOFF1(20),BLUEXOFF2(20),ENTRY1(10)
388         DIMENSION  BLUEYOFF2(20),BLUE1POS(10,20),BLUEY1POS(10,20)
389         DIMENSION  UNITSPD(10),VEHTYPE(10,20),BLUECODE(10),MINE1(10)
390         DIMENSION  BLUEYOFF0(20),BLUEXOFF0(20),MINERND(100),STATMIN1(10)
391         DIMENSION  BLUESTATUS(10,20),CLEAR(20),MOVE(20),DEPMINE1(10)
392         DIMENSION  BULL1(10),BYPASS1(10),DISTDET2(10,100),ENTRY2(10)
393         DIMENSION  MINE2(10),STATMIN2(10),DEPMINE2(10),BYPASS2(10)
394         DIMENSION  BULL2(10),MINEKILL(100),ROLLKILL(100),PLOWKILL(100)
395         DIMENSION  PLOWBRCHKILL(100),ROLLBRCHKILL(100),MTYPE(20)

396               MINEPK=.99
397               STEP=0.1
398               STEPMINE2=9.0
399               STEPMINE1=9.0
400               MINEDET1=0.1
401               MINEDET2=0.5
402               PCLEAR4=.861
403               PCLEAR5=.926
404               PDETONAT4=.10
405               PSURVIV4=.90
406               PSURVIV5=.75
407               PDETTNK4=.999
408               PDETTNK5=.978


    *       PRINT*,'BLUECODE',UNIT,BLUECODE(UNIT),LOC(UNIT)

409                   CALL GGUBS(DSEED,100,MINERND)

410         DO 70 KOUNT=1,5
411             LOC(UNIT)=AVE(UNIT,ISTART(UNIT))
412                   IF (BLUECODE(UNIT) .EQ. 0) THEN
413                         TRAVEL = 0
414                         UNITSPD(UNIT) = 0
415                         GO TO 75
416                   END IF

417             CALL SPD(TRAVEL,SPEED,LOC,STEP,UNIT,UNITSPD,VEHTYPE,NUMBLUE,
        *                 AAA,CLOSE,BEHIND,BLUESTATUS)
```

```
      IF (ENTRY1(UNIT) .EQ. 0) THEN
        IF (LOC(UNIT) .EQ. MINE1(UNIT) .AND. STATMIN1(UNIT) .EQ. 1) THEN
            IF (MINERND(1) .LT. MINEDET1) THEN
                    DO 33 K=1,NUMBLUE
                        IF (BLUESTATUS(UNIT,K) .EQ. 2) THEN
                            BLUESTATUS(UNIT,K) = 1
                        END IF
                        IF (VEHTYPE(UNIT,K) .EQ. 2 ) THEN
                             VEHTYPE(UNIT,K) = 4
                        ELSE IF (VEHTYPE(UNIT,K) .EQ. 3 ) THEN
                             VEHTYPE(UNIT,K) = 5
                        END IF
33                  CONTINUE
                        BLUECODE(UNIT)=2
                        CLEAR(UNIT)=3
          MOVE(UNIT)=0.001
                        ENTRY1(UNIT)=1

          WRITE(54,767) CLOCK,UNIT,LOC(UNIT),BLUECODE(UNIT)
767       FORMAT(2X,F4.1,' UNIT ',I1,' DETECTED MINE1 AT ',I3,
     *                                  ' BLUECODE IS ',I1)

                        GO TO 98
            ELSE IF (DISTDET1(UNIT,1) .LT. DISTANCE(UNIT)) THEN
          DO 52 I=1,NUMBLUE
              IF (BLUESTATUS(UNIT,I) .NE. 0) THEN
           RANGE1=(SQRT(((REDX-BLUEX1POS(UNIT,I))**2)+
     *           ((REDY-BLUEY1POS(UNIT,I))**2)))/10
                IF (RANGE1 .LT. STEPMINE1) THEN
                      STEPMINE1=RANGE1
                      ACTIVE1=I
                ELSE IF (RANGE1 .LT. STEPMINE2) THEN
                      STEPMINE2=RANGE1
                      ACTIVE2=I
                END IF
              END IF
52     CONTINUE
                        BLUECODE(UNIT) = 2

          WRITE(54,757) CLOCK,UNIT,LOC(UNIT),BLUECODE(UNIT)
757       FORMAT(2X,F4.1,' UNIT ',I1,' DETONATED MINE1 AT ',I3,
     *                              ' BLUECODE IS ',I1)

                IF (MINERND(2) .LT. MINEPK) THEN
                     BLUESTATUS(UNIT,ACTIVE1)=0
                     MINEKILL(REP)=MINEKILL(REP)+1
           MTYPE(VEHTYPE(UNIT,ACTIVE1))=MTYPE(VEHTYPE(UNIT,ACTIVE1))+1
           WRITE(54,913) UNIT,ACTIVE1,VEHTYPE(UNIT,ACTIVE1)
               IF (DISTDET1(UNIT,2) .LT. DISTANCE(UNIT) .AND.
     *                                MINERND(3) .LT. MINEPK) THEN
                       BLUESTATUS(UNIT,ACTIVE2) = 0
                   MINEKILL(REP)=MINEKILL(REP)+1
           MTYPE(VEHTYPE(UNIT,ACTIVE2))=MTYPE(VEHTYPE(UNIT,ACTIVE2))+1
           WRITE(54,913) UNIT,ACTIVE2,VEHTYPE(UNIT,ACTIVE2)
                END IF


                    DO 35 K=1,NUMBLUE
                        IF (BLUESTATUS(UNIT,K) .EQ. 2) THEN
```

```
                              BLUESTATUS(UNIT,K) = 1
                          END IF
                          IF (VEHTYPE(UNIT,K) .EQ. 2 ) THEN
                               VEHTYPE(UNIT,K) = 4
                          ELSE IF (VEHTYPE(UNIT,K) .EQ. 3 ) THEN
                               VEHTYPE(UNIT,K) = 5
                          END IF
 35                   CONTINUE
                           CLEAR(UNIT)=3
                          ENTRY1(UNIT)=1
            MOVE(UNIT)=DISTDET1(UNIT,CLEAR(UNIT))+DISTDET1(UNIT,1)


 913        FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' KILLED AT MINEFIELD 1',
     *                  ' MMMMMMMMMMMMMMMMMMMM')
                          GO TO 98
                  END IF
                      DO 59 K=1,NUMBLUE
                          IF (BLUESTATUS(UNIT,K) .EQ. 2) THEN
                              BLUESTATUS(UNIT,K) = 1
                          END IF
                          IF (VEHTYPE(UNIT,K) .EQ. 2 ) THEN
                               VEHTYPE(UNIT,K) = 4
                          ELSE IF (VEHTYPE(UNIT,K) .EQ. 3 ) THEN
                               VEHTYPE(UNIT,K) = 5
                          END IF
 59                   CONTINUE
                           CLEAR(UNIT)=3
                          ENTRY1(UNIT)=1
            MOVE(UNIT)=DISTDET1(UNIT,CLEAR(UNIT))+DISTDET1(UNIT,1)

                           GO TO 98
             END IF

          END IF
        ELSE IF (ENTRY2(UNIT) .EQ. 0) THEN
          IF (LOC(UNIT) .EQ. MINE2(UNIT) .AND. STATMIN2(UNIT) .EQ. 1) THEN
              IF (MINERND(1) .LT. MINEDET2) THEN
                      DO 99 K=1,NUMBLUE
                          IF (BLUESTATUS(UNIT,K) .EQ. 2) THEN
                              BLUESTATUS(UNIT,K) = 1
                          END IF
                          IF (VEHTYPE(UNIT,K) .EQ. 2 ) THEN
                               VEHTYPE(UNIT,K) = 4
                          ELSE IF (VEHTYPE(UNIT,K) .EQ. 3 ) THEN
                               VEHTYPE(UNIT,K) = 5
                          END IF
 99                   CONTINUE
                          BLUECODE(UNIT)=2
                          CLEAR(UNIT)=3
            MOVE(UNIT)=0.001
                          ENTRY2(UNIT)=1

          WRITE(54,766) CLOCK,UNIT,LOC(UNIT),BLUECODE(UNIT)
 766      FORMAT(2X,F4.1,' UNIT ',I1,' DETECTED MINE2 AT ',I3,
     *                                  ' BLUECODE IS ',I1)

                          GO TO 98
              ELSE IF (DISTDET2(UNIT,1) .LT. DISTANCE(UNIT)) THEN
          DO 96 I=1,NUMBLUE
```

```
519              IF (BLUESTATUS(UNIT,I) .NE. 0) THEN
520           RANGE1=(SQRT(((REDX-BLUEX1POS(UNIT,I))**2)+
     *             ((REDY-BLUEY1POS(UNIT,I))**2)))/10
521                IF (RANGE1 .LT. STEPMINE1) THEN
522                      STEPMINE1=RANGE1
523                      ACTIVE1=I
524                ELSE IF (RANGE1 .LT. STEPMINE2) THEN
525                      STEPMINE2=RANGE1
526                      ACTIVE2=I
527                END IF
528              END IF
529 96     CONTINUE
530                          BLUECODE(UNIT) = 2

531           WRITE(54,756) CLOCK,UNIT,LOC(UNIT),BLUECODE(UNIT)
532 756      FORMAT(2X,F4.1,' UNIT ',I1,' DETONATED MINE2 AT ',I3,
     *                              ' BLUECODE IS ',I1)

    *         PRINT*,'UNIT ACTIVE1 MINE2',UNIT,ACTIVE1
533               IF (MINERND(2) .LT. MINEPK) THEN
534                    BLUESTATUS(UNIT,ACTIVE1)=0
535                    MINEKILL(REP)=MINEKILL(REP)+1
536           MTYPE(VEHTYPE(UNIT,ACTIVE1))=MTYPE(VEHTYPE(UNIT,ACTIVE1))+1
537           WRITE(54,943) UNIT,ACTIVE1,VEHTYPE(UNIT,ACTIVE1)
538               IF (DISTDET2(UNIT,2) .LT. DISTANCE(UNIT) .AND.
     *                                  MINERND(3) .LT. MINEPK) THEN
539                      BLUESTATUS(UNIT,ACTIVE2) = 0
540                    MINEKILL(REP)=MINEKILL(REP)+1
541           MTYPE(VEHTYPE(UNIT,ACTIVE2))=MTYPE(VEHTYPE(UNIT,ACTIVE2))+1
542           WRITE(54,943) UNIT,ACTIVE2,VEHTYPE(UNIT,ACTIVE2)
543                END IF


544                     DO 95 K=1,NUMBLUE
545                          IF (BLUESTATUS(UNIT,K) .EQ. 2) THEN
546                              BLUESTATUS(UNIT,K) = 1
547                          END IF
548                          IF (VEHTYPE(UNIT,K) .EQ. 2 ) THEN
549                               VEHTYPE(UNIT,K) = 4
550                          ELSE IF (VEHTYPE(UNIT,K) .EQ. 3 ) THEN
551                               VEHTYPE(UNIT,K) = 5
552                          END IF
553 95                  CONTINUE
554                           CLEAR(UNIT)=3
555                          ENTRY2(UNIT)=1
556            MOVE(UNIT)=DISTDET2(UNIT,CLEAR(UNIT))+DISTDET2(UNIT,1)


557 943      FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' KILLED AT MINEFIELD 2',
     *                ' MMMMMMMMMMMMMMMMMMMMM')
558                          GO TO 98
559                END IF
560                     DO 94 K=1,NUMBLUE
561                          IF (BLUESTATUS(UNIT,K) .EQ. 2) THEN
562                              BLUESTATUS(UNIT,K) = 1
563                          END IF
564                          IF (VEHTYPE(UNIT,K) .EQ. 2 ) THEN
565                               VEHTYPE(UNIT,K) = 4
566                          ELSE IF (VEHTYPE(UNIT,K) .EQ. 3 ) THEN
567                               VEHTYPE(UNIT,K) = 5
```

```
568                         END IF
569 94                   CONTINUE
570                          CLEAR(UNIT)=3
571                         ENTRY2(UNIT)=1
572           MOVE(UNIT)=DISTDET2(UNIT,CLEAR(UNIT))+DISTDET2(UNIT,1)

573                         GO TO 98
574             END IF

575           END IF
576         END IF
577          IF (ENTRY1(UNIT) .EQ. 2) THEN
578           IF (LOC(UNIT) .EQ. MINE1(UNIT)) THEN
579                       IF (BULL1(UNIT) .EQ. 1) THEN
580                                GO TO 41
581                       ELSE IF (BYPASS1(UNIT) .EQ. 1) THEN
582                                GO TO 46
583                       END IF
584              IF (BULL1(UNIT) .EQ. 0 .AND. BYPASS1(UNIT) .EQ. 0) THEN
585                 DO 26 IIPSN=1,NUMBLUE
586                    IF (BLUESTATUS(UNIT,IIPSN) .EQ. 0) THEN
587                                     GO TO 26
588                    ELSE IF (VEHTYPE(UNIT,IIPSN) .EQ. 1) THEN
589                       IF (DISTANCE(UNIT) .GE. DEPMINE1(UNIT)/2) THEN
590                                     BULL1(UNIT) = 1
591                                     GO TO 46
592                       ELSE IF (DISTANCE(UNIT) .LT. DEPMINE1(UNIT)/2) THEN
593                                     BYPASS1(UNIT) = 1
594                                     GO TO 41
595                       END IF
596                    ELSE IF (VEHTYPE(UNIT,IIPSN) .NE. 1) THEN
597                                     GO TO 25
598                    END IF
599 26              CONTINUE
600              END IF

601 25          IF (MOVE(UNIT) .LT. DISTANCE(UNIT)) THEN
602                   DO 37 IPSN = 1,NUMBLUE
603                        IF (BLUESTATUS(UNIT,IPSN) .EQ. 0) THEN
604                        GO TO 37
605                        END IF
606                  IF (VEHTYPE(UNIT,IPSN) .EQ. 1) THEN
607                         IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
608                         BLUESTATUS(UNIT,IPSN) = 0
609                      MINEKILL(REP)=MINEKILL(REP)+1
610                    MTYPE(VEHTYPE(UNIT,IPSN))=MTYPE(VEHTYPE(UNIT,IPSN))+1
611           WRITE(54,940) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
612 940       FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' KILLED IN MINEFIELD 1 ',
          *             'DUE TO UNCLEARED MINE')
613                         GO TO 36
614                         ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
615                         GO TO 36
616                         END IF
617                  ELSE IF (VEHTYPE(UNIT,IPSN) .EQ. 4) THEN
618                       IF (MINERND(CLEAR(UNIT)) .LT. PCLEAR4) THEN
619                         CLEAR(UNIT)= CLEAR(UNIT) + 1
620                          IF (MINERND(CLEAR(UNIT)) .GE. PDETONAT4) THEN
621           WRITE(54,641) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
622 641       FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED A MINE',
          *             ' IN MINEFIELD 1 SSSS')
```

```
623                         CLEAR(UNIT)= CLEAR(UNIT) + 1
624                            GO TO 36
625                       ELSE IF (MINERND(CLEAR(UNIT)) .LT. PDETONAT4) THEN
626                         CLEAR(UNIT)= CLEAR(UNIT) + 1
627                          IF (MINERND(CLEAR(UNIT)) .LT. PSURVIV4) THEN
628           WRITE(54,941) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
629 941       FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/SURVIVED BLAST',
          *          ' IN MINEFIELD 1 SSSS')
630                            GO TO 36
631                         ELSE IF (MINERND(CLEAR(UNIT)) .GE. PSURVIV4) THEN
632           WRITE(54,942) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
633 942       FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/PLOW DID NOT ',
          *          ' SURVIVE IN MINEFIELD 1')
634                            PLOWKILL(REP)=PLOWKILL(REP)+1
635                            VEHTYPE(UNIT,IPSN) = 1
636                            TEMPTYPE=VEHTYPE(UNIT,IPSN)
637                            TEMPSTATUS=BLUESTATUS(UNIT,IPSN)
638                            TEMPDETECT=BLUEDETECT1(UNIT,IPSN)
639                                  DO 61 PSN=IPSN,NUMBLUE-1
640                                 VEHTYPE(UNIT,PSN)=VEHTYPE(UNIT,PSN+1)
641                             BLUESTATUS(UNIT,PSN)= BLUESTATUS(UNIT,PSN+1)
642                             BLUEDETECT1(UNIT,PSN)=BLUEDETECT1(UNIT,PSN+1)
643 61                               CONTINUE
644                            BLUESTATUS(UNIT,NUMBLUE)=TEMPSTATUS
645                            VEHTYPE(UNIT,NUMBLUE)=TEMPTYPE
646                            BLUEDETECT1(UNIT,NUMBLUE)=TEMPDETECT
647                            GO TO 36
648                         END IF
649                       END IF
650             ELSE IF (MINERND(CLEAR(UNIT)) .LT. PDETTNK4 .AND.
          *                MINERND(CLEAR(UNIT)) .GT. PCLEAR4)  THEN
651                           CLEAR(UNIT)=CLEAR(UNIT)+1
652                      IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
653           WRITE(54,945) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
654 945       FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' PLOW FAILED TO CLEAR ',
          *          'MINE/CARRIER WAS KILLED')
655                      BLUESTATUS(UNIT,IPSN) = 0
656                      PLOWBRCHKILL(REP)=PLOWBRCHKILL(REP)+1
657                      GO TO 36
658                      ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
659                      GO TO 36
660                      END IF
661             ELSE IF (MINERND(CLEAR(UNIT)) .GE. PDETTNK4) THEN
662                           CLEAR(UNIT)=CLEAR(UNIT)+1
663           WRITE(54,946) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
664 946       FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' PLOW FAILED TO CLEAR ',
          *          'MINE/CARRIER SURVIVED')
665           WRITE(54,947)
666 947       FORMAT('MINE LEFT IN PATH UNEXPLODED')
667                            GO TO 37
668             END IF
669           ELSE IF (VEHTYPE(UNIT,IPSN) .EQ. 5) THEN
670             IF (MINERND(CLEAR(UNIT)) .LT. PCLEAR5) THEN
671                 CLEAR(UNIT)= CLEAR(UNIT) + 1
672               IF (MINERND(CLEAR(UNIT)) .LT. PSURVIV5) THEN
673           WRITE(54,901) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
674 901       FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/SURVIVED A MINE',
          *          ' IN MINEFIELD 1 SSSS')
675                      GO TO 36
676               ELSE IF (MINERND(CLEAR(UNIT)) .GE. PSURVIV5) THEN
```

```
677         WRITE(54,944) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
678 944     FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/ROLLER DIDNOT',
        *             ' SURVIVE IN MINEFIELD 1')
679                   ROLLKILL(REP)=ROLLKILL(REP)+1
680                       VEHTYPE(UNIT,IPSN) = 1
681                       TEMPTYPE=VEHTYPE(UNIT,IPSN)
682                       TEMPSTATUS=BLUESTATUS(UNIT,IPSN)
683                       TEMPDETECT=BLUEDETECT1(UNIT,IPSN)
684           DO 65 PSN=IPSN,NUMBLUE-1
685                 VEHTYPE(UNIT,PSN)=VEHTYPE(UNIT,PSN+1)
686                 BLUESTATUS(UNIT,PSN)= BLUESTATUS(UNIT,PSN+1)
687                 BLUEDETECT1(UNIT,PSN)=BLUEDETECT1(UNIT,PSN+1)
688 65                CONTINUE
689                 BLUESTATUS(UNIT,NUMBLUE)=TEMPSTATUS
690                 VEHTYPE(UNIT,NUMBLUE)=TEMPTYPE
691                 BLUEDETECT1(UNIT,NUMBLUE)=TEMPDETECT
692                       GO TO 36
693               END IF
694             ELSE IF (MINERND(CLEAR(UNIT)) .LT. PDETTNK5 .AND.
        *                    MINERND(CLEAR(UNIT)) .GT. PCLEAR5)  THEN
695                           CLEAR(UNIT)=CLEAR(UNIT)+1
696                  IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
697                         BLUESTATUS(UNIT,IPSN) = 0
698           WRITE(54,955) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
699 955     FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' ROLLER FAILED TO CLEAR ',
        *              'MINE/CARRIER WAS KILLED')
700                   ROLLBRCHKILL(REP)=ROLLBRCHKILL(REP)+1
701                           GO TO 36
702                   ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
703                            GO TO 36
704                   END IF
705             ELSE IF (MINERND(CLEAR(UNIT)) .GE. PDETTNK5) THEN
706                           CLEAR(UNIT)=CLEAR(UNIT)+1
707           WRITE(54,948) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
708 948     FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' ROLLER FAILED TO CLEAR ',
        *              'MINE/CARRIER SURVIVED')
709           WRITE(54,949)
710 949     FORMAT('MINE LEFT IN PATH UNEXPLODED')
711                          GO TO 37
712             END IF
713             END IF
714 37       CONTINUE
715 36                       CLEAR(UNIT)=CLEAR(UNIT)+1
716                        MOVE(UNIT)=DISTDET1(UNIT,CLEAR(UNIT))+MOVE(UNIT)
717             IF (DISTANCE(UNIT) .GT. DEPMINE1(UNIT)) THEN
718                                  ENTRY1(UNIT)=3
719               IF (BLUECODE(UNIT) .NE. 0) THEN
720                         BLUECODE(UNIT) = 1
721                       DO 38 K=1,NUMBLUE
722                 IF (VEHTYPE(UNIT,K) .EQ. 4 ) THEN
723                           VEHTYPE(UNIT,K) = 2
724                 ELSE IF (VEHTYPE(UNIT,K) .EQ. 5 ) THEN
725                           VEHTYPE(UNIT,K) = 3
726                 END IF
727 38        CONTINUE
728               END IF
729             END IF
730           END IF
731         END IF
732       END IF
```

```
      IF (BULL1(UNIT).EQ. 1) THEN
                        TRAVEL=TRAVEL/10
         IF(MOVE(UNIT) .LT. DISTANCE(UNIT)) THEN
            DO 21 IPSN = 1,NUMBLUE
                IF (BLUESTATUS(UNIT,IPSN) .EQ. 0) THEN
                   GO TO 21
                END IF
                IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
                    BLUESTATUS(UNIT,IPSN) = 0
                    MINEKILL(REP)=MINEKILL(REP)+1
               MTYPE(VEHTYPE(UNIT,IPSN))=MTYPE(VEHTYPE(UNIT,IPSN))+1
      WRITE(54,967) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
967   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' KILLED IN MINEFIELD 1 ',
     *          'DUE TO BULLING THRU ')
                    GO TO 71
                 ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
                    GO TO 71
                 END IF
21          CONTINUE
                       CLEAR(UNIT)=CLEAR(UNIT)+1
                    MOVE(UNIT)=DISTDET1(UNIT,CLEAR(UNIT))+MOVE(UNIT)
         IF (DISTANCE(UNIT) .GT. DEPMINE1(UNIT)) THEN
                                ENTRY1(UNIT)=3
           IF (BLUECODE(UNIT) .NE. 0) THEN
                     BLUECODE(UNIT) = 1
                    BULL1(UNIT) = 2
                    GO TO 75
          END IF
         END IF
      END IF
          END IF

      IF (BYPASS1(UNIT).EQ. 1) THEN
                     TRAVEL=TRAVEL/40
          IF (KOUNT .EQ.5) THEN
      WRITE(54,968) UNIT
968   FORMAT(' UNIT ',I3,' IS CONDUCTING BYPASS OPERATION AROUND ',
     *          'MINEFIELD 1 PPPPPPP ')
          END IF
         IF (DISTANCE(UNIT) .GT. DEPMINE1(UNIT)) THEN
                             ENTRY1(UNIT)=3
           IF (BLUECODE(UNIT) .NE. 0) THEN
                     BLUECODE(UNIT) = 1
                    BYPASS1(UNIT) = 2
      END IF
      END IF
         END IF


      IF (ENTRY2(UNIT) .EQ. 2) THEN
       IF (LOC(UNIT) .EQ. MINE2(UNIT)) THEN
                    IF (BULL2(UNIT) .EQ. 1) THEN
                              GO TO 93
                    ELSE IF (BYPASS2(UNIT) .EQ. 1) THEN
                              GO TO 92
                    END IF
         IF (BULL2(UNIT) .EQ. 0 .AND. BYPASS2(UNIT) .EQ. 0) THEN
            DO 91 IIPSN=1,NUMBLUE
               IF (BLUESTATUS(UNIT,IIPSN) .EQ. 0) THEN
                                   GO TO 91
```

```
788                   ELSE IF (VEHTYPE(UNIT,IIPSN) .EQ. 1) THEN
789                      IF (DISTANCE(UNIT) .GE. DEPMINE2(UNIT)/2) THEN
790                                    BULL2(UNIT) = 1
791                                    GO TO 92
792                      ELSE IF (DISTANCE(UNIT) .LT. DEPMINE2(UNIT)/2) THEN
793                                    BYPASS2(UNIT) = 1
794                                    GO TO 93
795                      END IF
796                   ELSE IF (VEHTYPE(UNIT,IIPSN) .NE. 1) THEN
797                                    GO TO 72
798                   END IF
799 91             CONTINUE
800              END IF

801 72          IF (MOVE(UNIT) .LT. DISTANCE(UNIT)) THEN
802                DO 73 IPSN = 1,NUMBLUE
803                     IF (BLUESTATUS(UNIT,IPSN) .EQ. 0) THEN
804                     GO TO 73
805                     END IF
806                IF (VEHTYPE(UNIT,IPSN) .EQ. 1) THEN
807                       IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
808                       BLUESTATUS(UNIT,IPSN) = 0
809                       MINEKILL(REP)=MINEKILL(REP)+1
810                  MTYPE(VEHTYPE(UNIT,IPSN))=MTYPE(VEHTYPE(UNIT,IPSN))+1
811          WRITE(54,741) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
812 741      FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' KILLED IN MINEFIELD 2 ',
         *             'DUE TO UNCLEARED MINE')
813                       GO TO 78
814                       ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
815                       GO TO 78
816                       END IF
817                ELSE IF (VEHTYPE(UNIT,IPSN) .EQ. 4) THEN
818                       IF (MINERND(CLEAR(UNIT)) .LT. PCLEAR4) THEN
819                       CLEAR(UNIT)= CLEAR(UNIT) + 1
820                        IF (MINERND(CLEAR(UNIT)) .GE. PDETONAT4) THEN
821          WRITE(54,341) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
822 341      FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED A MINE',
         *             ' IN MINEFIELD 2 SSSS')
823                       CLEAR(UNIT)= CLEAR(UNIT) + 1
824                          GO TO 78
825                     ELSE IF (MINERND(CLEAR(UNIT)) .LT. PDETONAT4) THEN
826                       CLEAR(UNIT)= CLEAR(UNIT) + 1
827                        IF (MINERND(CLEAR(UNIT)) .LT. PSURVIV4) THEN
828          WRITE(54,981) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
829 981      FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/SURVIVED BLAST',
         *             ' IN MINEFIELD 2 SSSS')
830                          GO TO 78
831                       ELSE IF (MINERND(CLEAR(UNIT)) .GE. PSURVIV4) THEN
832          WRITE(54,982) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
833 982      FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/PLOW DID NOT ',
         *             ' SURVIVE IN MINEFIELD 2')
834                        PLOWKILL(REP)=PLOWKILL(REP)+1
835                        VEHTYPE(UNIT,IPSN) = 1
836                        TEMPTYPE=VEHTYPE(UNIT,IPSN)
837                        TEMPSTATUS=BLUESTATUS(UNIT,IPSN)
838                        TEMPDETECT=BLUEDETECT1(UNIT,IPSN)
839                              DO 53 PSN=IPSN,NUMBLUE-1
840                             VEHTYPE(UNIT,PSN)=VEHTYPE(UNIT,PSN+1)
841                         BLUESTATUS(UNIT,PSN)= BLUESTATUS(UNIT,PSN+1)
842                         BLUEDETECT1(UNIT,PSN)=BLUEDETECT1(UNIT,PSN+1)
```

```
843 53                              CONTINUE
844                               BLUESTATUS(UNIT,NUMBLUE)=TEMPSTATUS
845                               VEHTYPE(UNIT,NUMBLUE)=TEMPTYPE
846                               BLUEDETECT1(UNIT,NUMBLUE)=TEMPDETECT
847                               GO TO 78
848                             END IF
849                         END IF
850                 ELSE IF (MINERND(CLEAR(UNIT)) .LT. PDETTNK4 .AND.
        *                        MINERND(CLEAR(UNIT)) .GT. PCLEAR4)  THEN
851                               CLEAR(UNIT)=CLEAR(UNIT)+1
852                           IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
853           WRITE(54,975) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
854 975       FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' PLOW FAILED TO CLEAR ',
        *             'MINE/CARRIER WAS KILLED')
855                       BLUESTATUS(UNIT,IPSN) = 0
856                       PLOWBRCHKILL(REP)=PLOWBRCHKILL(REP)+1
857                       GO TO 78
858                       ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
859                       GO TO 78
860                       END IF
861                 ELSE IF (MINERND(CLEAR(UNIT)) .GE. PDETTNK4) THEN
862                               CLEAR(UNIT)=CLEAR(UNIT)+1
863           WRITE(54,976) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
864 976       FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' PLOW FAILED TO CLEAR ',
        *             'MINE/CARRIER SURVIVED')
865           WRITE(54,937)
866 937       FORMAT('MINE LEFT IN PATH UNEXPLODED')
867                               GO TO 73
868                 END IF
869               ELSE IF (VEHTYPE(UNIT,IPSN) .EQ. 5) THEN
870                 IF (MINERND(CLEAR(UNIT)) .LT. PCLEAR5) THEN
871                     CLEAR(UNIT)= CLEAR(UNIT) + 1
872                   IF (MINERND(CLEAR(UNIT)) .LT. PSURVIV5) THEN
873           WRITE(54,933) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
874 933       FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/SURVIVED A MINE',
        *             ' IN MINEFIELD 2 SSSS')
875                       GO TO 78
876                 ELSE IF (MINERND(CLEAR(UNIT)) .GE. PSURVIV5) THEN
877           WRITE(54,934) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
878 934       FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/ROLLER DIDNOT',
        *             ' SURVIVE IN MINEFIELD 2')
879                       ROLLKILL(REP)=ROLLKILL(REP)+1
880                           VEHTYPE(UNIT,IPSN) = 1
881                           TEMPTYPE=VEHTYPE(UNIT,IPSN)
882                           TEMPSTATUS=BLUESTATUS(UNIT,IPSN)
883                           TEMPDETECT=BLUEDETECT1(UNIT,IPSN)
884             DO 45 PSN=IPSN,NUMBLUE-1
885                   VEHTYPE(UNIT,PSN)=VEHTYPE(UNIT,PSN+1)
886                   BLUESTATUS(UNIT,PSN)= BLUESTATUS(UNIT,PSN+1)
887                   BLUEDETECT1(UNIT,PSN)=BLUEDETECT1(UNIT,PSN+1)
888 45                CONTINUE
889                   BLUESTATUS(UNIT,NUMBLUE)=TEMPSTATUS
890                   VEHTYPE(UNIT,NUMBLUE)=TEMPTYPE
891                   BLUEDETECT1(UNIT,NUMBLUE)=TEMPDETECT
892                         GO TO 78
893                 END IF
894               ELSE IF (MINERND(CLEAR(UNIT)) .LT. PDETTNK5 .AND.
        *                        MINERND(CLEAR(UNIT)) .GT. PCLEAR5)  THEN
895                               CLEAR(UNIT)=CLEAR(UNIT)+1
896                   IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
```

```
                        BLUESTATUS(UNIT,IPSN) = 0
        WRITE(54,935) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
935     FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' ROLLER FAILED TO CLEAR ',
     *           'MINE/CARRIER WAS KILLED')
                ROLLBRCHKILL(REP)=ROLLBRCHKILL(REP)+1
                              GO TO 78
                ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
                               GO TO 78
                END IF
             ELSE IF (MINERND(CLEAR(UNIT)) .GE. PDETTNK5) THEN
                              CLEAR(UNIT)=CLEAR(UNIT)+1
        WRITE(54,938) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
938     FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' ROLLER FAILED TO CLEAR ',
     *           'MINE/CARRIER SURVIVED')
        WRITE(54,939)
939     FORMAT('MINE LEFT IN PATH UNEXPLODED')
                             GO TO 73
             END IF
             END IF
73       CONTINUE
78                           CLEAR(UNIT)=CLEAR(UNIT)+1
                          MOVE(UNIT)=DISTDET2(UNIT,CLEAR(UNIT))+MOVE(UNIT)
             IF (DISTANCE(UNIT) .GT. DEPMINE2(UNIT)) THEN
                                  ENTRY2(UNIT)=3
               IF (BLUECODE(UNIT) .NE. 0) THEN
                    BLUECODE(UNIT) = 1
                         DO 48 K=1,NUMBLUE
                  IF (VEHTYPE(UNIT,K) .EQ. 4 ) THEN
                              VEHTYPE(UNIT,K) = 2
                  ELSE IF (VEHTYPE(UNIT,K) .EQ. 5 ) THEN
                              VEHTYPE(UNIT,K) = 3
                  END IF
48       CONTINUE
             END IF
          END IF
        END IF
       END IF
93       IF (BULL2(UNIT).EQ. 1) THEN
                     TRAVEL=TRAVEL/10
            IF(MOVE(UNIT) .LT. DISTANCE(UNIT)) THEN
               DO 82 IPSN = 1,NUMBLUE
                   IF (BLUESTATUS(UNIT,IPSN) .EQ. 0) THEN
                      GO TO 82
                   END IF
                   IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
                       BLUESTATUS(UNIT,IPSN) = 0
                   MINEKILL(REP)=MINEKILL(REP)+1
                  MTYPE(VEHTYPE(UNIT,IPSN))=MTYPE(VEHTYPE(UNIT,IPSN))+1
        WRITE(54,957) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
957     FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' KILLED IN MINEFIELD 2 ',
     *           'DUE TO BULLING THRU ')
                       GO TO 84
                    ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
                       GO TO 84
                    END IF
82             CONTINUE
84                           CLEAR(UNIT)=CLEAR(UNIT)+1
                          MOVE(UNIT)=DISTDET2(UNIT,CLEAR(UNIT))+MOVE(UNIT)
             IF (DISTANCE(UNIT) .GT. DEPMINE2(UNIT)) THEN
```

```
                                        ENTRY2(UNIT)=3
                IF (BLUECODE(UNIT) .NE. 0) THEN
                          BLUECODE(UNIT) = 1
                         BULL2(UNIT) = 2
                         GO TO 75
                END IF
              END IF
            END IF
                END IF

 92         IF (BYPASS2(UNIT).EQ. 1) THEN
                          TRAVEL=TRAVEL/50
                  IF (KOUNT .EQ.5) THEN
          WRITE(54,977) UNIT
 977      FORMAT(' UNIT ',I3,' IS CONDUCTING BYPASS OPERATION AROUND ',
     *             'MINEFIELD 2 PPPPPPP ')
                END IF
              IF (DISTANCE(UNIT) .GT. DEPMINE2(UNIT)) THEN
                                      ENTRY2(UNIT)=3
                IF (BLUECODE(UNIT) .NE. 0) THEN
                          BLUECODE(UNIT) = 1
                         BYPASS2(UNIT) = 2
            END IF
            END IF
               END IF


 75             DELX=TRAVEL*COS(ANGLE(LOC(UNIT)))*10
                DELY=TRAVEL*SIN(ANGLE(LOC(UNIT)))*10
                BLUEXPOS(UNIT)=BLUEXPOS(UNIT)+DELX
                BLUEYPOS(UNIT)=BLUEYPOS(UNIT)+DELY

            CALL OFFSET (BLUEXPOS,BLUEYPOS,BLUEXOFF1,BLUEYOFF1,LOC,
     *                  ANGLE,UNIT,NUMBLUE,CLOCK,KOUNT,BLUECODE,
     *                  BLUEXOFF2,BLUEYOFF2,BLUEX1POS,BLUEY1POS,
     *                  BLUEXOFF0,BLUEYOFF0)

                DISTANCE(UNIT)=DISTANCE(UNIT)+TRAVEL

          IF (DISTANCE(UNIT) .GE. DIST(LOC(UNIT))) THEN
                ISTART(UNIT)=ISTART(UNIT)+1
                LOC(UNIT) = AVE(UNIT,ISTART(UNIT))
                DISTANCE(UNIT)=0.0
              BLUEXPOS(UNIT) = XNODE(TAIL(LOC(UNIT)))
              BLUEYPOS(UNIT) = YNODE(TAIL(LOC(UNIT)))
              GO TO 98
          END IF
 70          CONTINUE
           GO TO 98

          WRITE(54,931) CLOCK,UNIT,LOC(UNIT),BLUEXPOS(UNIT),BLUEYPOS(UNIT),
     *                  UNITSPD(UNIT),RNG(UNIT)
 931        FORMAT(2X,F4.1,' UNIT ',I3,' LOC ',I3,
     *              ' POSITION ',2F6.1,' SPEED ',F4.0,' RANGE ',F8.3)

 98           RETURN
              END
```

****

```
     ***************** SPEED ****************************************
 997         SUBROUTINE SPD(TRAVEL,SPEED,LOC,STEP,UNIT,UNITSPD,VEHTYPE,
          *                 NUMBLUE,AAA,CLOSE,BEHIND,BLUESTATUS)
 998               INTEGER LOC,UNIT,VEHTYPE,NUMBLUE,VEH,CLOSE,BEHIND
 999               INTEGER BLUESTATUS
1000               REAL SPEED,TRAVEL,STEP,UNITSPD,AAA
1001               DIMENSION SPEED(10,80),LOC(10),UNITSPD(10),VEHTYPE(10,20)
1002               DIMENSION BLUESTATUS(10,20)

1003                     UNITSPD(UNIT)=160

1004            DO 23 VEH=1,NUMBLUE
1005         IF(BLUESTATUS(UNIT,VEH) .NE. 0) THEN
1006         IF(SPEED(VEHTYPE(UNIT,VEH),LOC(UNIT)) .LT. UNITSPD(UNIT)) THEN
1007                     UNITSPD(UNIT)=SPEED(VEHTYPE(UNIT,VEH),LOC(UNIT))

1008                  END IF
1009                  END IF
1010 23          CONTINUE

1011           IF (BEHIND .EQ. 1 .AND. CLOSE .EQ. UNIT) THEN
1012                UNITSPD(UNIT) = UNITSPD(UNIT)/AAA
1013                TRAVEL = (UNITSPD(UNIT)/60)*STEP
1014                GO TO 51
1015           END IF

1016                TRAVEL = (UNITSPD(UNIT)/60)*STEP

1017 51             RETURN
1018                  END

     ***************************************************************************
```

```
      ********** OFFSET **********

1019        SUBROUTINE OFFSET (BLUEXPOS,BLUEYPOS,BLUEXOFF1,BLUEYOFF1,
           *          LOC,ANGLE,UNIT,NUMBLUE,CLOCK,KOUNT,
           *          BLUECODE,BLUEXOFF2,BLUEYOFF2,BLUEX1POS,BLUEY1POS,
           *          BLUEXOFF0,BLUEYOFF0)

1020        INTEGER LOC,UNIT,C,KOUNT,NUMBLUE,BLUECODE
1021        REAL BLUEX1PLT,BLUEY1PLT,ANGLE,BLUEXPOS,BLUEYPOS
1022        REAL XOFFPLT,YOFFPLT,CLOCK
1023        REAL BLUEXOFF1,BLUEXOFF2,BLUEYOFF1,BLUEYOFF2,BLUEX1POS,BLUEY1POS
1024        REAL BLUEXOFF0,BLUEYOFF0
1025        DIMENSION BLUEXOFF1(20),BLUEYOFF1(20),ANGLE(100),BLUECODE(10)
1026        DIMENSION BLUEXOFF0(20),BLUEYOFF0(20)
1027        DIMENSION BLUEX1POS(10,20),BLUEY1POS(10,20),LOC(10)
1028        DIMENSION BLUEXPOS(20),BLUEYPOS(20),BLUEXOFF2(20),BLUEYOFF2(20)

1029          DO 60 C=1,NUMBLUE
1030         IF (BLUECODE(UNIT) .EQ. 0) THEN
1031             XOFFPLT=BLUEXOFF0(C)
1032             YOFFPLT=BLUEYOFF0(C)
1033         ELSE IF (BLUECODE(UNIT) .EQ. 1) THEN
1034             XOFFPLT=BLUEXOFF1(C)
1035             YOFFPLT=BLUEYOFF1(C)
1036         ELSE IF (BLUECODE(UNIT) .EQ. 2) THEN
1037             XOFFPLT=BLUEXOFF2(C)
1038             YOFFPLT=BLUEYOFF2(C)
1039         END IF
1040          BLUEX1POS(UNIT,C)=BLUEXPOS(UNIT)+(XOFFPLT*COS(ANGLE(LOC(UNIT)))
           *                        +YOFFPLT*SIN(ANGLE(LOC(UNIT))))
1041          BLUEY1POS(UNIT,C)=BLUEYPOS(UNIT)+(-XOFFPLT*SIN(ANGLE(LOC(UNIT)))
           *                        +YOFFPLT*COS(ANGLE(LOC(UNIT))))

1042 60       CONTINUE



1043             RETURN
1044                END

      **********
```

```
      ******************  DETECTION  ************************************

1045            SUBROUTINE REDDETECT (REDXPOS,REDYPOS,BLUEXPOS,BLUEYPOS,
          *                   BLUEX1POS,BLUEY1POS,NUNIT,REDENGAGE,BLUESTATUS,
          *                   ANGLE,UNIT,UNITSPD,CLOCK,LOC,CV,NUMRED,NUMBLUE,
          *                   REDX,REDY,RED,RPLOOK,REDSTATUS,DSEED,VEHTYPE,
          *                   REDDETECT1,REDDETECT2,ELEMENT,POSITION,TAU,
          *                   RVEHTYP,BLUECODE,RMAX)

1046            INTEGER UNIT,LOC,NUMRED,RED,REDSTATUS,VEHTYPE,REDENGAGE
1047            INTEGER REDDETECT1,REDDETECT2,ELEMENT,POSITION,NUNIT
1048            INTEGER BLUESTATUS,RVEHTYP,BLUECODE
1049            REAL REDXPOS,REDYPOS,BLUEXPOS,BLUEYPOS
1050            REAL BLUEX1POS,BLUEY1POS,ANGLE,UNITSPD
1051            REAL CLOCK,CV,REDX,REDY,HEIGHT,TAU,DENOM,RPLOOK,REDPDET
1052            REAL RAND,RMAX,RAF,RNGADJ,RNGDET1,RNGDET2,RANGE1,RANGE2
1053            REAL*8 DSEED
1054          DIMENSION  BLUEXPOS(20),BLUEYPOS(20),LOC(10),UNITSPD(10),CV(10)
1055          DIMENSION  BLUEX1POS(10,20),BLUEY1POS(10,20),ANGLE(100)
1056          DIMENSION  RED(30),REDXPOS(30),REDYPOS(30),RPLOOK(10,30)
1057          DIMENSION  RAND(10),REDSTATUS(30),RMAX(30),TEMP(30)
1058          DIMENSION  VEHTYPE(10,20),HEIGHT(20),RAF(8),REDENGAGE(100)
1059          DIMENSION  REDDETECT1(30),REDDETECT2(30),RNGDET1(30),RNGDET2(30)
1060          DIMENSION  BLUESTATUS(10,20),RVEHTYP(30),BLUECODE(10)

1061            HEIGHT(1)=2.4
1062            HEIGHT(2)=2.4
1063            HEIGHT(3)=2.4
1064            HEIGHT(4)=2.4
1065            HEIGHT(5)=2.4

1066             RNGDET1(ELEMENT)=300.0
1067             RANGE1=0.0
1068             RNGDET2(ELEMENT)=500.0
1069             RANGE2=0.0
1070             REDDETECT1(ELEMENT)=0
1071             REDDETECT2(ELEMENT)=0


1072                DO 39 I=1,3
1073                   RAF(I)=.000
1074 39          CONTINUE
1075                   RAF(4)=.10
1076                   RAF(5)=.10
```

```
     *  LOOP 77 NUMBER OF BLUE UNITS
1077           DO 77 UNIT=1,NUNIT

1078         IF (BLUECODE(UNIT) .EQ. 0 ) THEN
1079                 CV(UNIT) = 0
1080                 GO TO 66
1081         END IF
1082                 OBSVECX=REDX-BLUEXPOS(UNIT)
1083                 OBSVECY=REDY-BLUEYPOS(UNIT)
1084                 DIRVECX=COS(ANGLE(LOC(UNIT)))
1085                 DIRVECY=SIN(ANGLE(LOC(UNIT)))
1086               OBSVECL=SQRT((OBSVECX**2)+(OBSVECY**2))
1087               CVANGLE=ACOS(((OBSVECX*DIRVECX)+(OBSVECY*DIRVECY))/OBSVECL)
1088               CV(UNIT) = (UNITSPD(UNIT)*1000/3600)*SIN(CVANGLE)


     *  LOOP 79 NUMBER OF BLUE ELEMENTS IN EACH UNIT
1089 66                 DO 79  POSITION=1,NUMBLUE
1090                           IF (BLUESTATUS(UNIT,POSITION) .EQ. 0) THEN
1091                                   GO TO 79
1092                           END IF

1093                    CALL GGUBS(DSEED,3,RAND)

1094            RANGE=(SQRT(((REDXPOS(ELEMENT)-BLUEX1POS(UNIT,POSITION))**2)+
        *             ((REDYPOS(ELEMENT)-BLUEY1POS(UNIT,POSITION))**2)))/10
1095              IF (BLUECODE(UNIT) .EQ. 0) THEN
1096          RNGAPP=(RANGE*2.8)/(((HEIGHT(VEHTYPE(UNIT,POSITION))/2)*RAND(1))
        *                                +(HEIGHT(VEHTYPE(UNIT,POSITION))/4))
1097                 GO TO 55
1098               END IF

1099          RNGAPP=(RANGE*2.8)/(((HEIGHT(VEHTYPE(UNIT,POSITION))/2)*RAND(1))
        *                                +(HEIGHT(VEHTYPE(UNIT,POSITION))/2))

1100 55             IF (RANGE .LT. .250) THEN
1101                        REDPDET=1.0
1102                      GO TO 34
1103                END IF

1104                     DENOM=1.453+(TAU*(.05978+(2.188*RNGAPP*RNGAPP)-
        *                          .5038*CV(UNIT)))
1105                     DETRATE=RPLOOK(UNIT,ELEMENT)*(-.003+(1.088/DENOM))

1106                  IF (DETRATE .LE. 0.0) THEN
1107                   DETRATE = 0.0
1108                  ELSE IF (DETRATE .GT. 5.0) THEN
1109                   REDPDET=1.0
1110                   GO TO 34
1111                  END IF

1112                     REDPDET=1-EXP(-DETRATE*30)
1113 34      IF (REDENGAGE(((NUMBLUE*(UNIT-1))+POSITION)) .GE. 2) THEN
1114                     GO TO 79
1115                   END IF

1116              IF (REDPDET .GE. RAND(2)) THEN
1117                IF (RANGE .LE. RMAX(ELEMENT)) THEN
```

```
1118            RNGADJ=(RANGE/(1-(RAND(3)/2))) + RAF(VEHTYPE(UNIT,POSITION))

1119                IF (RNGADJ .LT. RNGDET1(ELEMENT)) THEN
1120                      RNGDET1(ELEMENT) = RNGADJ
1121                      RANGE1=RANGE
1122                        REDSTATUS(ELEMENT) = 2
1123                 REDDETECT1(ELEMENT)=(NUMBLUE*(UNIT-1))+POSITION
1124                ELSE IF (RNGADJ .LT. RNGDET2(ELEMENT)) THEN
1125                   IF(RVEHTYP(ELEMENT) .EQ. 1) THEN
1126                      RNGDET2(ELEMENT) = RNGADJ
1127                      RANGE2=RANGE
1128                        REDSTATUS(ELEMENT) = 2
1129                     REDDETECT2(ELEMENT)= (NUMBLUE*(UNIT-1))+POSITION
1130                   END IF
1131                END IF
1132             END IF
1133          END IF


1134 79       CONTINUE
1135 77       CONTINUE
1136           IF (RNGDET1(ELEMENT) .LT. 200.0) THEN
1137          REDENGAGE(REDDETECT1(ELEMENT))=REDENGAGE(REDDETECT1(ELEMENT))+1
1138           END IF
1139           IF (RNGDET2(ELEMENT) .LT. 200.0) THEN

1140          REDENGAGE(REDDETECT2(ELEMENT))=REDENGAGE(REDDETECT2(ELEMENT))+1

1141             END IF

1142            RETURN
1143             END

      ************************************************************************


1144             SUBROUTINE BLUEDETECT (REDXPOS,REDYPOS,BLUEX1POS,BLUEY1POS,
          *          BLUEENGAGE,BLUESTATUS,REDSTATUS,DSEED,UNIT,CLOCK,NUMRED,
          *          BLUEDETECT1,ELEMENT,POSITION,TAU,RVEHTYP,RHEIGHT,RRAF,
          *          BLUERMAX)
1145             INTEGER UNIT,NUMRED,REDSTATUS
1146             INTEGER BLUEDETECT1,ELEMENT,POSITION
1147             INTEGER BLUESTATUS,RVEHTYP,BLUEENGAGE
1148             REAL REDXPOS,REDYPOS
1149             REAL BLUEX1POS,BLUEY1POS,DETRATE
1150             REAL CLOCK,RHEIGHT,TAU,DENOM,RNGAPP,RANGE,BLUEPDET
1151             REAL RUND,BLUERMAX,RRAF,RNGADJ,RNGDET,RANGE1
1152             REAL*8 DSEED
1153           DIMENSION  BLUEX1POS(10,20),BLUEY1POS(10,20)
1154           DIMENSION  REDXPOS(30),REDYPOS(30)
1155           DIMENSION  RUND(10),REDSTATUS(30),BLUERMAX(10,20)
1156           DIMENSION  BLUEDETECT1(10,20),RNGDET(10,20),BLUEENGAGE(30)
1157           DIMENSION  BLUESTATUS(10,20),RVEHTYP(30),RRAF(4),RHEIGHT(30)

1158           RNGDET(UNIT,POSITION)=300
1159           RANGE1=0.0
1160           BLUEDETECT1(UNIT,POSITION)=0


1161           DO 29 ELEMENT=1,NUMRED
```

```
1162                IF(REDSTATUS(ELEMENT) .EQ. 0) THEN
1163                     GO TO 29
1164                END IF
1165                   CALL GGUBS(DSEED,3,RUND)

1166           RANGE=(SQRT(((REDXPOS(ELEMENT)-BLUEX1POS(UNIT,POSITION))**2)+
          *          ((REDYPOS(ELEMENT)-BLUEY1POS(UNIT,POSITION))**2)))/10

1167         RNGAPP=(RANGE*2.8)/(((RHEIGHT(ELEMENT)/2)*RUND(1))
          *                              +(RHEIGHT(ELEMENT)/4))

1168                IF (RANGE .LT. .250) THEN
1169                       BLUEPDET=1.0
1170                     GO TO 14
1171                END IF

1172                     DENOM=1.453+(TAU*(.05978+(2.188*RNGAPP*RNGAPP)))

1173                     DETRATE=.75*(-.003+(1.088/DENOM))

1174                 IF (DETRATE .LE. 0.0) THEN
1175                  DETRATE = 0.0
1176                 ELSE IF (DETRATE .GT. 5.0) THEN
1177                  BLUEPDET=1.0
1178                  GO TO 14
1179                 END IF

1180                     BLUEPDET=1-EXP(-DETRATE*30)
1181 14      IF (BLUEENGAGE(ELEMENT) .GE. 4) THEN
1182                   GO TO 29
1183                  END IF

1184            IF (BLUEPDET .GE. RUND(2)) THEN
1185                 IF (RANGE .LE. BLUERMAX(UNIT,POSITION)) THEN

1186             RNGADJ=(RANGE/(.25+(RUND(3)/4)) + RRAF(RVEHTYP(ELEMENT)))

1187             IF (RNGADJ .LT. RNGDET(UNIT,POSITION)) THEN
1188                        RNGDET(UNIT,POSITION) = RNGADJ
1189                         RANGE1=RANGE
1190                          BLUESTATUS(UNIT,POSITION) = 2
1191                   BLUEDETECT1(UNIT,POSITION)=ELEMENT
1192             END IF
1193             END IF
1194            END IF


1195 29       CONTINUE
1196            IF (RNGDET(UNIT,POSITION) .LT. 200.0) THEN
1197          BLUEENGAGE(BLUEDETECT1(UNIT,POSITION))=
          *                BLUEENGAGE(BLUEDETECT1(UNIT,POSITION))+1

1198            END IF

1199             RETURN
1200               END
     ***************************************************************************
```

```
      ******************   FIRE   ************************************

1201        SUBROUTINE REDFIRE(REDSTATUS,ELEMENT,REDENGAGE,BLUESTATUS,UNIT,
           *             POSITION,NUMBLUE,REDXPOS,REDYPOS,NUNIT,VEHTYPE,
           *             REDDETECT1,REDDETECT2,BLUEX1POS,BLUEY1POS,DSEED,
           *             CLOCK,RVEHTYP,RPHITS,RPHITM,RPKILL,DFKILL,REP,DFTYPE)
1202        INTEGER REDSTATUS,ELEMENT,REDENGAGE,BLUESTATUS,UNIT,POSITION
1203        INTEGER NUMBLUE,SHOT,REDDETECT1,REDDETECT2,LOOP,NUNIT,RVEHTYP
1204        INTEGER VEHTYPE,DFKILL,REP,DFTYPE
1205        REAL RANGE,REDXPOS,REDYPOS,BLUEX1POS,BLUEY1POS
1206        REAL PHIT,PKILL,RNDNUM,CLOCK,RPHITS,RPHITM,RPKILL
1207        REAL*8 DSEED
1208        DIMENSION REDSTATUS(30),REDENGAGE(100),REDXPOS(30),DFKILL(100)
1209        DIMENSION REDDETECT1(30),REDDETECT2(30),REDYPOS(30),VEHTYPE(10,20)
1210        DIMENSION BLUESTATUS(10,20),BLUEX1POS(10,20),BLUEY1POS(10,20)
1211        DIMENSION RNDNUM(10),RVEHTYP(30),RPHITS(10),RPHITM(10),RPKILL(10)
1212        DIMENSION DFTYPE(10)

1213           REDSTATUS(ELEMENT)=1

1214           SHOT=REDDETECT1(ELEMENT)
1215              LOOP = 1
1216               GO TO 67

1217 97        SHOT = REDDETECT2(ELEMENT)
1218               LOOP = 2

1219 67           IF (SHOT .EQ. 0) THEN
1220                 GO TO 87
1221              ELSE IF (SHOT .GT. 0) THEN
1222                DO 27 I=1,NUNIT
1223                   IF (SHOT .LE. I*NUMBLUE) THEN
1224                  UNIT = I
1225                  POSITION = SHOT - ((UNIT-1)*NUMBLUE)
1226                  GO TO 88
1227                   END IF
1228 27              CONTINUE
1229              END IF
1230 88      RANGE=(SQRT(((REDXPOS(ELEMENT)-BLUEX1POS(UNIT,POSITION))**2)+
           *          ((REDYPOS(ELEMENT)-BLUEY1POS(UNIT,POSITION))**2)))/10

1231           IF (RVEHTYP(ELEMENT) .EQ. 2) THEN
1232              IF(RANGE .LT. .250) THEN
1233                 PHIT = RPHITM(5)
1234                 PKILL = RPKILL(5)
1235               ELSE IF (RANGE .LT. 1.000) THEN
1236                 PHIT = RPHITM(6)
1237                 PKILL = RPKILL(6)
1238               ELSE IF (RANGE .LT. 1.500) THEN
1239                 PHIT = RPHITM(7)
1240                 PKILL = RPKILL(7)
1241               ELSE IF (RANGE .LT. 2.500) THEN
1242                 PHIT = RPHITM(8)
1243                 PKILL = RPKILL(8)
1244               ELSE IF (RANGE .LT. 4.400) THEN
1245                 PHIT = RPHITM(9)
1246                 PKILL = RPKILL(9)
1247               END IF
1248              GO TO 76
1249              END IF

1250              IF(RANGE .LT. .500) THEN
```

```
1251                PHIT = RPHITM(1)
1252                PKILL = RPKILL(1)
1253              ELSE IF (RANGE .LT. 1.000) THEN
1254                PHIT = RPHITM(2)
1255                PKILL = RPKILL(2)
1256              ELSE IF (RANGE .LT. 2.000) THEN
1257                PHIT = RPHITM(3)
1258                PKILL = RPKILL(3)
1259              ELSE IF (RANGE .LT. 3.300) THEN
1260                PHIT = RPHITM(4)
1261                PKILL = RPKILL(4)
1262              END IF
1263 76         CALL GGUBS(DSEED,2,RNDNUM)
1264              IF (BLUESTATUS(UNIT,POSITION) .EQ. 0) GO TO 87
1265                  IF (RNDNUM(1) .LE. PHIT) THEN
1266                        IF (RNDNUM(2) .LE. PKILL) THEN
1267                              BLUESTATUS(UNIT,POSITION) = 0
1268                              DFKILL(REP)=DFKILL(REP)+1
1269            DFTYPE(VEHTYPE(UNIT,POSITION))=DFTYPE(VEHTYPE(UNIT,POSITION))+1
1270                         REDENGAGE((NUMBLUE*(UNIT-1))+POSITION) = 2
1271         WRITE(54,747) CLOCK,ELEMENT,RANGE,UNIT,POSITION,
        *                  VEHTYPE(UNIT,POSITION)
1272 747     FORMAT(1X,F5.1,' RED ',I2,' RANGE ',F6.3,
        *    ' KILLED BLUE',2I3,' VEHTYPE ',I2,' BBBBBBBBBBB')
1273                              GO TO 87
1274                          END IF
1275                  END IF

1276            REDENGAGE((NUMBLUE*(UNIT-1))+POSITION) =
        *             REDENGAGE((NUMBLUE*(UNIT-1))+POSITION) - 1

1277 87       IF (LOOP .EQ. 1) THEN
1278            GO TO 97
1279          END IF
1280                 RETURN
1281                  END
     ******************************************************************************


1282         SUBROUTINE BLUEFIRE(REDSTATUS,ELEMENT,BLUEENGAGE,BLUESTATUS,UNIT,
        *              POSITION,REDXPOS,REDYPOS,RVEHTYP,
        *              BLUEDETECT1,BLUEX1POS,BLUEY1POS,DSEED,
        *              CLOCK,BPHITS,BPKILL)
1283         INTEGER REDSTATUS,ELEMENT,BLUEENGAGE,BLUESTATUS,UNIT,POSITION
1284         INTEGER BLUEDETECT1,RVEHTYP
1285         REAL RANGE,REDXPOS,REDYPOS,BLUEX1POS,BLUEY1POS
1286         REAL PHIT,PKILL,RNDNUB,CLOCK,BPHITS,BPKILL
1287         REAL*8 DSEED
1288         DIMENSION REDSTATUS(30),BLUEENGAGE(30),REDXPOS(30)
1289         DIMENSION BLUEDETECT1(10,20),REDYPOS(30)
1290         DIMENSION BLUESTATUS(10,20),BLUEX1POS(10,20),BLUEY1POS(10,20)
1291         DIMENSION RNDNUB(10),RVEHTYP(30),BPHITS(10),BPKILL(10)

1292            BLUESTATUS(UNIT,POSITION)=1
1293            ELEMENT=BLUEDETECT1(UNIT,POSITION)
1294          RANGE=(SQRT(((REDXPOS(ELEMENT)-BLUEX1POS(UNIT,POSITION))**2)+
        *             ((REDYPOS(ELEMENT)-BLUEY1POS(UNIT,POSITION))**2)))/10

1295           IF (RVEHTYP(ELEMENT) .EQ. 2) THEN
1296             IF(RANGE .LT. .500) THEN
```

```
1297                PHIT = BPHITS(5)
1298                PKILL = BPKILL(5)
1299             ELSE IF (RANGE .LT. 1.000) THEN
1300                PHIT = BPHITS(6)
1301                PKILL = BPKILL(6)
1302             ELSE IF (RANGE .LT. 2.000) THEN
1303                PHIT = BPHITS(7)
1304                PKILL = BPKILL(7)
1305             ELSE IF (RANGE .LT. 3.300) THEN
1306                PHIT = BPHITS(8)
1307                PKILL = BPKILL(8)
1308             END IF
1309          GO TO 74
1310            END IF

1311             IF(RANGE .LT. .500) THEN
1312                PHIT = BPHITS(1)
1313                PKILL = BPKILL(1)
1314             ELSE IF (RANGE .LT. 1.000) THEN
1315                PHIT = BPHITS(2)
1316                PKILL = BPKILL(2)
1317             ELSE IF (RANGE .LT. 2.000) THEN
1318                PHIT = BPHITS(3)
1319                PKILL = BPKILL(3)
1320             ELSE IF (RANGE .LT. 3.300) THEN
1321                PHIT = BPHITS(4)
1322                PKILL = BPKILL(4)
1323             END IF

1324 74         CALL GGUBS(DSEED,2,RNDNUB)
1325               IF (REDSTATUS(ELEMENT) .EQ. 0) GO TO 83
1326                  IF (RNDNUB(1) .LE. PHIT) THEN
1327                        IF (RNDNUB(2) .LE. PKILL) THEN
1328                             REDSTATUS(ELEMENT) = 0
1329                        BLUEENGAGE(ELEMENT) = 4
1330        WRITE(54,777) CLOCK,UNIT,POSITION,RANGE,ELEMENT
1331 777    FORMAT(1X,F5.1,' BLUE ',2I4,' AT RANGE ',F6.3,' KILLED RED ',I3,
     *             ' RRRRRRRRRRRRRR')
1332                             GO TO 83
1333                          END IF
1334                  END IF

1335             BLUEENGAGE(ELEMENT) = BLUEENGAGE(ELEMENT)-1


1336 83             RETURN
1337                 END
     ******************************************************************************
```

APPENDIX C

DATA FILES TO SUPPORT THE PROGRAM

This appendix contains the data files used in the program listed in Appendix B. Most data files can be expanded or reduced as long as the appropriate parameters are changed in the program.

The network is supported by the MINEMET data file shown below. The first column is the arc number, the second column is the node number of the tail of the arc while the third column is the node number of the head of the arc. The fourth column is the distance associated with the arc while the last column is the heading of the arc in radians.

1	1	2	2.92	5.616
2	1	3	3.13	5.989
3	2	13	1.44	5.692
4	3	4	0.67	1.107
5	3	5	1.25	0.499
6	4	7	1.86	0.633
7	5	6	0.54	0.381
8	7	8	0.41	6.141
9	6	9	0.48	0.322
10	8	11	1.26	6.141
11	9	10	0.92	6.056
12	10	22	1.23	6.064
13	11	12	1.00	6.141
14	12	26	0.61	0.000
15	13	14	0.92	6.064
16	14	19	1.84	0.704
17	19	20	0.81	0.704
18	14	15	0.92	5.865
19	15	16	0.70	6.005
20	16	17	0.62	0.464
21	17	18	0.71	1.373
22	18	23	0.76	0.785
23	23	24	0.71	0.785
24	24	25	0.99	0.785
25	20	21	0.64	0.675
26	21	22	0.99	0.644
27	22	26	0.54	0.927
28	25	26	0.82	1.816
29	26	27	0.70	5.819
30	27	28	0.53	0.927
31	28	29	0.00	0.000

The NODLOC file is the physical location of each node in the network. The first column is the node, the second is the x coordinate while the third is the y coordinate. If the x and y coordinate were put together they would represent the standard six digit grid coordinate system.

1	583	229
2	606	211
3	613	220
4	616	226
5	624	226
6	635	230
7	631	237
8	635	236
9	639	231
10	648	229
11	647	232
12	657	232
13	618	203
14	627	201
15	636	197
16	643	195
17	649	198
18	650	205
19	640	214
20	647	218
21	652	222
22	660	228
23	653	212
24	658	217
25	665	224
26	663	232
27	669	229
28	672	233
29	672	233

The Avenue Data is used to support the Movement network. Each value is an arc number, with each avenue represented by a column of arcs. The last arc in the network, arc 31 is an arc with no speed associated with it, so if a unit reaches that arc (which is past the objective) it would essentially remain in position unitl the arrival of the rest of the units.

2	2	1	1
4	5	3	3
6	7	15	15
8	9	16	18
10	11	17	19
13	12	25	20
14	27	26	21
29	29	27	22
30	30	29	23
31	31	30	24
31	31	31	28
31	31	31	29
31	31	31	30

The SPEED file represents the speeds that the various types of equipment in the unit are able to maintain over the various arcs. The speeds are affected by terrain, roads, cities and other natural objects such as forests. The columns in order represent an M1, a mineplow tank with the plow in the raised position, a mineroller tank with the rollers in the position, a mineplow tank with the plow employed, and finally the mineroller tank in the breaching mode.
raised position, a mineroller tank with the roller

27	21	16	9	12
27	21	16	9	12
27	21	16	9	12
20	13	10	9	8
24	19	13	8	10
27	21	16	9	12
24	19	13	8	10
27	21	16	9	12
27	21	16	9	12
27	21	16	9	12
27	21	16	9	12
27	21	16	9	12
20	13	10	9	8
13	8	7	4	5
27	21	16	9	12
27	21	16	9	12
27	21	16	9	12
27	21	16	9	12
27	21	16	9	12
33	26	19	9	12
33	26	19	9	12
27	21	16	9	12
27	21	16	9	12
27	21	16	9	12
27	21	16	9	12
27	21	16	9	12
17	11	8	5	7
27	21	16	9	12
27	21	16	9	12
40	31	24	9	12
27	21	16	9	12

This file is used to input the type and order of the equipment in each ofthe units. The only three codes used are: 1 for an M1, 2 for a mineplow tank, and three for a mineroller tank. The vehicles can be placed in any order and the units do not have to be configured the same, either in the type of equipment or the order in which it is entered.

```
2  2  2  2
2  2  2  2
3  3  3  3
3  3  3  3
1  1  1  1
1  1  1  1
1  1  1  1
1  1  1  1
1  1  1  1
1  1  1  1
1  1  1  1
1  1  1  1
1  1  1  1
1  1  1  1
```

The following is an example of the file that support the formations. The offsets in the x and y directions are given in hundreds of meters, therefore the value -2.50 would be two hundred and fifty meters in either the minus x direction if it was in the first column or the minus y direction if it was in the second column.

-5.00	.00
-7.00	.00
-6.50	.50
-6.50	-.50
-6.00	.00
-0.50	4.00
-0.50	-4.00
-1.00	-3.50
-0.50	-3.00
-0.50	3.00
-1.00	3.50
.00	.00
.00	-3.50
.00	3.50

The data used in this file represents the blue probability of hitting a target given a range band and then the probability of killing the target given a hit. The first column is the hit probability while the second is the kill probability.

X.XX X.XX
X.XX X.XX
X.XX X.XX
X.XX X.XX
X.XX X.XX
X.XX X.XX
X.XX X.XX
X.XX X.XX

The REDPOSN file represents the physical location of each red element in the unit. The first column is the element number, the secon is the x coordinate, and the third is the y coordinate. If the two coordinates were put together they would represent a standard eight digit grid coordinate.

1	666.5	228.0
2	668.0	228.5
3	665.5	230.0
4	663.5	229.5
5	663.5	230.5
6	662.0	231.5
7	662.0	232.5
8	661.0	235.0
9	661.5	235.0
10	663.5	233.0
11	667.0	229.5
12	665.5	231.0
13	663.5	232.0

The RPLOOK file is used in the red DETECTION subroutine and represents the probability that the observer is looking in the direction of the target, in this case each of the four avenues of approach used by the blue forces. They are user input and the probability of looking in all directions does not have to add to 1.

0.10	0.10	0.35	0.40
0.10	0.10	0.35	0.40
0.10	0.10	0.35	0.40
0.10	0.25	0.40	0.20
0.10	0.25	0.40	0.20
0.10	0.25	0.40	0.20
0.40	0.40	0.10	0.05
0.40	0.40	0.10	0.05
0.40	0.40	0.10	0.05
0.25	0.25	0.25	0.25
0.05	0.10	0.40	0.40
0.05	0.10	0.40	0.40
0.30	0.40	0.15	0.10

The RVEHTYP file supports the red unit in terms of type of equipment, height, range adjustment factor and maximum effective range. The first column is the vehicle type, with a 1 representing a tank, while a 2 represents a BMP. Column 2 is the height of the vehicle while column 3 is the range adjustment factor (RAF) used in the simulation. The RAF represents the range difference that would be required between a tank and a BMP before the the BMP would be engaged. The last column is the maximum effective range of the weapon system.

```
1  2.3  0    3.0
1  2.3  0    3.0
1  2.3  0    3.0
1  2.3  0    3.0
1  2.3  0    3.0
1  2.3  0    3.0
1  2.3  0    3.0
1  2.3  0    3.0
1  2.3  0    3.0
1  2.3  0    3.0
2  2.1  0.4  4.0
2  2.1  0.4  4.0
2  2.1  0.4  4.0
```

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